COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES APPROPRIATIONS FOR 2011

HEARINGS

BEFORE A

SUBCOMMITTEE OF THE

COMMITTEE ON APPROPRIATIONS

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

SUBCOMMITTEE ON COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES

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NOTE: Under Committee Rules, Mr. Obey, as Chairman of the Full Committee, and Mr. Lewis, as Ranking Minority Member of the Full Committee, are authorized to sit as Members of all Subcommittees.

JOHN BLAZEY, DIXON BUTLER, ADRIENNE SIMONSON,
DIANA SIMPSON, DAREK NEWBY, and BRAD DANIELS,
Subcommittee Staff

PART 7

Printed for the use of the Committee on Appropriations

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COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES APPROPRIATIONS FOR 2011

WEDNESDAY, FEBRUARY 3, 2010.

SCIENCE, TECHNOLOGY, ENGINEERING AND MATH EDUCATION

WITNESSES

DR. OLIVER HILL, VIRGINIA STATE UNIVERSITY

DR. ELEANOR MIELE, BROOKLYN COLLEGE

Mr. MOLLOHAN. Good morning. The hearing will come to order.

Welcome to the first hearing of the Subcommittee on Commerce, Justice, and Science for fiscal year 2011.

Before we begin our initial hearing, a bit of housekeeping. I would like to reiterate for the benefit of members of the Subcommittee that it is my intention to recognize in order of seniority those members present at the start of each hearing followed by members in order of their attendance. This continues the policy we had in place last year.

Turning now to today's business, in testimony before this Subcommittee last year, it was stated that U.S. graduate education in science, technology, engineering, and mathematics, STEM, is the model for the world and undergraduate STEM education is among the best in the world. However, testimony also revealed that K through 12 STEM education in the United States is woefully lacking in preparing our students to compete and innovate in the changing world economy.

We learned last year that it is essential for students before the age of ten to see themselves as becoming scientists and engineers or they will not choose these fields for study when they are older.

Advances in STEM hold the key to the future economic growth of the United States and the essential resource on which this program will be built is today's children.

In fiscal year 2010, this Subcommittee added appropriations for K through 12 STEM education and STEM teacher preparation to the budgets of NSF, NOAA, and NASA with the expectation that these funds will be used in part to improve STEM education in grades K–6 and that they will contribute to efforts to embed inquiry-based instruction in science education. The fiscal year 2011 budget request continues many of these investments.

Our hearing is particularly timely given Tuesday's New York Times op-ed by Susan Engel of Williams College entitled *Playing* *to Learn*. In it, she describes an ideal elementary education as follows, and I quote:

"In our theoretical classroom, children would also spend a short period of time each day practicing computation, adding, subtracting, multiplying, and dividing. Once children are proficient in those basics, they would be free to turn to other activities that are equally essential for math and science, devising original experiments, observing the natural world and counting things, whether they be words, events, or people. These are all activities children naturally love if given the chance to do them in a genuine way."

Achieving this ideal is a key goal of our appropriations for STEM education. Today and tomorrow we will hear from witnesses who have examples of improvements in STEM education that are ongoing. Through their testimony, we will see the effects of federal investments and learn more about the challenges of improving STEM education and adopting inquiry-based learning.

Today we will hear from Dr. Oliver Hill, Virginia State University, and Dr. Eleanor Miele of Brooklyn College. Dr. Hill has helped improve math achievement for students in the public schools of Petersburg, Virginia. His testimony will shed light on another point in Dr. Engel's op-ed. She states, and I quote, "In order to design a curriculum that teaches what truly matters, educators should remember a basic precept of modern developmental science. Development precursors don't always resemble the skill to which they are leading," end of quote.

Dr. Miele has just written a textbook on inquiry and has worked with K through 12 teachers to include inquiry in their science teaching and to make effective use of their surroundings in New York City.

Thank you both for coming.

Following the opening statement of Ranking Member Wolf, we will ask each of you to provide a summary of your written testimony which we will include in the hearing record and then we will go to questions from Subcommittee members.

Mr. Wolf.

Mr. WOLF. Thank you, Mr. Chairman.

I am pleased to join the Chairman in welcoming our expert witnesses today on science, technology, engineering, and math education starting our hearing schedule for the fiscal year 2011 appropriations cycle.

I look forward to working again with you, Mr. Chairman, and the rest of the members of the Committee because we have such a wide-ranging jurisdiction.

This is an important hearing. I know that looking at the STEM money for higher education grants last year that almost 50 percent of the STEM money that was appropriated laid on the table and no one accessed it. And so the money, that figure could be 50, could be 40, again, but a lot of money was appropriated and was not used.

The Committee had a language in their working with Mr. Mollohan that we asked the National Science Foundation to look at what programs are working around the country in math and science and physics and chemistry and biology with young people and put together a best practices that can go into every school or school district in the country.

But I think even if you fund the money, if you do not have the interest and do not have people pursuing it, you know, and so when you look at what has taken place.

So I think that is one of the problems. How do you create the interest? We are graduating fewer physicists, Ph.D. physicists today than we did in 1956. And the world has changed and physics is awful important.

And I think it is a big issue and so I appreciate you are here for your testimony.

And I thank you, Chairman, for having this hearing and I yield back.

Mr. MOLLOHAN. Thank you, Mr. Wolf.

Dr. Hill.

MATHEMATICS EDUCATION

Dr. HILL. Thank you, Mr. Chairman.

And I would like to thank the Committee for this opportunity to speak to you today. I do think this is an important topic.

I am the principal investigator on two grants from the National Science Foundation to Virginia State University that are studying innovative approaches to improve the mathematic performance primarily of minority students in the local Petersburg school district. We know that a mathematics background and competence are the primary gatekeepers to a STEM career.

When we started working with the Petersburg district in 2007, it was the lowest performing school district in the State. None of its schools were accredited. And by 2009, all but two of the schools were fully accredited and those two missed it by just a few points. We expect all to be accredited this year.

On standardized mathematics performance, the two schools we worked directly with had 127 percent and 74 percent increases in scores respectively.

Our project was not the only thing at work here. For one thing, they hired a new dynamic superintendent, which had a big impact on the district. But our research indicated the dynamic effect our interventions were having on the students.

The project involved training teachers in the innovative pedagogy the Algebra Project and organizing the community around support for the schools.

The Algebra Project curriculum was developed by Dr. Robert Moses, who was a recipient of MacArthur Genius Award. The pedagogy helps students connect abstract mathematical principles to their every-day language and experience.

The Algebra Project approach also relies heavily on community involvement. With their help, we are in the process of developing what we are calling a K through 16 model with Petersburg and the University with the idea that we need to make contact with students early and often starting at the kindergarten level and grooming them toward a STEM career.

This relationship involves programs like dual enrollment courses, providing math and science grad students as teachers, providing college students tutors, and providing services to students through involvements of departments like psychology, sociology, and nursing because many of the problems that these kids face are not academic issues.

COGNITIVE TRAINING

One of the most innovative aspects of our project is testing the impact of cognitive training on the mathematics performance of students. Students coming from low socioeconomic status backgrounds and even many with middle-class backgrounds often lack the capacity for abstract thinking required for success in higher level mathematics and science courses. This is a major barrier to pursuing STEM related careers.

These deficiencies are usually addressed through content-based remediation and tutoring programs, but there have been numerous studies documenting the failure of these types of content-based interventions to have meaningful impacts on basic skill development or educational achievement, particularly among minority students.

The approach of direct cognitive training represents a unique method of developing the underlying thinking skills needed for success in STEM. This approach is not the usual teaching of critical thinking skills which represent fairly high level cognitive processing, but rather builds the basic architecture of cognition by training basic cognitive skills such as processing, speed, attention, and working memory.

At one time, it was thought that these kinds of skills were set by the time that one reached adolescence, but we now know that these skills are malleable even into adulthood.

We have been using the procedures developed by an educational firm called Learning RX which runs cognitive learning centers around the country. The data collected in these centers over the last few years has indicated tremendous gains of three to four grade levels in reading and other cognitive skills after only 15 weeks of a fairly intense one-on-one intervention.

We are testing whether meaningful results can be obtained using an on-line version of this program that can be administered in groups, which would be much more practical in a school setting. Our initial data looks very promising.

This approach has the potential to revolutionize education in general and STEM education in particular. We think it addresses one of the primary development problems that block success in mathematics and science classes, that is weak cognitive skills.

THE ROLE OF HBCUS

I teach at Virginia State University which is a historically black university and I want to speak for a moment about the role that HBCUs can play in addressing the under-representation of minorities in STEM careers.

HBCUs have the students who could fill those majors. VSU loses literally hundreds of potential STEM majors each year because of difficulties with math. We need to focus more research dollars to investigators at HBCUs to develop promising interventions to attract and hold minority students in STEM majors.

Initiatives targeted to HBCUs at funding agencies like NSF and NIH need to receive greater support. And if I could build on what Mr. Wolf was saying, one of the difficulties at largely teaching universities like HBCUs is kind of a catch 22. You have to have the publication record. You have to have the time to put on research in order to attract the federal dollars. We need to have more innovative programs that allow particularly young investigators at the HBCUs to have the time to devote to both developing a research program and being able to write competitive grants that would be funded by agencies like NSF and NIH. But the human capital is there both in terms of the investigators and in terms of the students that could be impacted.

EDUCATION CRISIS

Finally, I would like to say the crisis in STEM education is but one facet of the larger crisis in education that we face as a nation. We know what quality education looks like. We can look at the curriculum of the best schools in any city.

And in Richmond, we have a school, Maggie Walker Governor's School, which is one of the best in the nation. If you look at the kind of rich programs they provide, this is the kind of curriculum that all students should be exposed to. Yet, for too long, we as a nation have said it was okay for millions of our students in inner cities and poor rural communities to receive substandard education with watered-down curricula and poor instruction. This is human capital we cannot afford to squander. It could represent untold resources for our country. We need to take the position that quality education is a civil right for all children in this country and we need to develop the political will to make that a reality.

So I will be happy to supply more details of any aspects of the interventions I mentioned during the period of questioning. And, again, thank you for this opportunity.

[The information follows:]

Commerce, Justice & Science Subcommittee – STEM Education Hearings

February 3, 2010

Oliver W. Hill, Jr., Ph.D.
Professor and Chair,
Department of Psychology
Virginia State University
Petersburg, Virginia

I am the Principal Investigator on two grants from the National Science Foundation to Virginia State University which are studying innovative approaches to improve the mathematics performance of minority students in the local Petersburg Public School District. We know that mathematics background and competence are the primary gatekeepers to STEM careers.

When we started working with the Petersburg district in 2007, it was the lowest-performing school district in the state. None of its schools were accredited. In 2009, all but two of the schools were fully accredited, and those two missed it by a few points. We expect all to be accredited this year. On standardized mathematical performance, the two schools we worked directly with had 127% and 74% increases in scores, respectively.

Our project wasn't the only thing at work here. A new, dynamic superintendent, Dr. James Victory, was hired during the second project year, for example. But our research indicated the dynamic effect that our interventions were having on the students.

The project involved training teachers in the innovative pedagogy of the Algebra Project, and organizing the community around support for the schools. The Algebra Project curriculum was developed by Dr. Robert Moses, who was the recipient of a MacArthur "genius" award. The pedagogy helps students connect abstract mathematical principles to their everyday language and experience. The Algebra Project approach also relies heavily on community involvement. With their help, we are in the process of developing a "K-16" model with Petersburg and the university, with the approach that we need to make contact with students early in their educational experience, and groom them toward STEM programs. This relationship involves programs like dual enrollment courses, providing math and science grad students as teachers, providing college student tutors, and providing services to students through the involvement of departments like psychology, sociology and nursing.

One of the most innovative aspects of our project is testing the impact of cognitive training on the mathematics performance of students. Students coming from low SES backgrounds (and many with middle class backgrounds) often lack the capacity for abstract thinking required for success in higher-level mathematics and science courses, and this is a major barrier to pursuing a STEM-related career. These deficiencies are usually addressed through content-based remediation and tutoring programs, but there have been numerous studies documenting the failure of these types of content-based interventions to have meaningful impacts on basic skill development or educational achievement, particularly among minority students.

The approach of direct cognitive *training* represents a unique method of developing the underlying thinking skills needed for success in STEM. This approach is not the usual teaching of "critical thinking" skills, which represent fairly high-level cognitive processing, but rather it builds the basic architecture of cognition by training basic cognitive skills such as processing speed, attention, and working memory. At one time it was thought that these kinds of skills were set by the time one reached adolescence, but we now know that these skills are malleable, even into adulthood.

We have been using the procedures developed by an educational firm called LearningRx, which runs cognitive learning centers around the country. The data collected in these centers over the last few years has indicated tremendous gains of three to four grade levels in reading and other cognitive skills after only 15 weeks of fairly intense one-on-one interventions. We are testing whether meaningful results can be obtained using an on-line version of the program that can be administered in groups, which would be more practical in a school setting. Our initial data looks very promising.

This approach has the potential to revolutionize education in general, and STEM education in particular. We think this addresses one of the primary developmental problems that blocks success in mathematics and science classes – weak cognitive skills.

I teach at Virginia State University (VSU), which is an HBCU, and I want to speak for a moment about the role that HBCU's can play in addressing the underrepresentation of minorities in STEM careers. HBCU's have the students who could fill those majors – VSU loses literally hundreds of potential STEM majors each year because of difficulties with math. We need to focus more research dollars to investigators at HBCU's to develop promising interventions to attract and hold minority students in STEM majors. Initiatives targeted to HBCU's at funding agencies like NSF and NIH need to receive greater support.

Finally, the crisis in STEM education is but one facet of the larger crisis in education that we face as a nation. We know what quality education looks like – we can look at the curriculum of the best schools in any city, such as the Maggie Walker Governor's School in Richmond, or the Appomattox Governor's School in Petersburg and see the rich programs they provide. Yet for too long we as a nation have said it was okay for millions of our students in inner cities and poor rural communities to receive substandard education with watered down curricula and poor instruction. This is human capital we can't afford to squander that could represent untold resources for our country.

We need to take the position that quality education is a civil right for all children in this country, and we need to develop the political will to make that a reality.

I'll be happy to supply more details on any aspects of the interventions I mentioned during the period of questioning.

Thank you.

Mr. MOLLOHAN. Thank you, Dr. Hill.

Dr. MIELE. Good morning, and thank you for this opportunity to speak to you all today.

I just want to start out by saying that I concur—am I not on?

Mr. MOLLOHAN. Is the light on?

Dr. MIELE. The light is on.

Mr. MOLLOHAN. Maybe you should pull it a little closer.

Dr. MIELE. Closer to me. Let us try that. Let us make sure.

Mr. MOLLOHAN. Maybe it is not going to come closer.

Dr. HILL. I think your cord is stuck.

Dr. MIELE. May I? That one gives feedback. Now you can hear me?

Mr. MOLLOHAN. Yeah, I can. Is this one not working at all?

Dr. MIELE. This one is not apparently working.

Mr. MOLLOHAN. Okay.

Dr. MIELE. But we can share.

Mr. MOLLOHAN. Dr. Hill, can you pull that cord over a little bit. Put you to work here this morning. Just pull it over toward her, I think.

Dr. MIELE. There we go.

Mr. MOLLOHAN. Our senior senator in West Virginia, Senator Byrd, has a common joke almost every time you speak out in public on the campaign trail, the sound system does not work and talks about our being able to do lots of things, but not a good sound system. I think we had a good sound system.

Dr. MIELE. Okay. Now we are on.

Mr. MOLLOHAN. Yes.

Dr. MIELE. And it is in front of me. So I wanted to start out by saying thank you. I concur with everything that Dr. Hill said.

DOING SCIENCE—INQUIRY

Science and math are intimately connected and the skills really can be developed in very much the same way. They need to be practiced. And we have known for over a hundred years that the best way to teach young people science is to allow them to do science. John Dewey pointed this out to us and it has been the right of every privileged student in private school to have constructivist education and to be doing science. It just has not happened in public schools.

DRIVERS OF CURRICULUM CHOICES

One of the reasons, I believe, is because the culture in public schools is very divorced from the culture in higher education. Research is usually not what drives choices. And I actually did not say that in my original testimony, but it became very clear to me listening to Dr. Hill that that is something we need to think about.

The choices that are made of curriculum are done at the local level and they are decided mostly by teachers and parents. The teachers that teach elementary school science are not scientists, and they tend to want to teach the way they were taught. And they were taught by direct instruction and memorization and that is what they fall back on.

When elementary school teachers are taught to use inquiry it is what they want to do, but very often their principals will not allow it. The principals are concerned that wasting time figuring out how we know what we know will keep them from learning enough and will affect standardized test scores and make the school look like it is not performing well.

INQUIRY-BASED INSTRUCTION AND EVALUATION

It is ironic that some of the classroom where inquiry is allowed to happen are the special education classrooms. And I actually heard reports of schools where the special education students outperformed the general education students on the New York State Assessment of Science Education.

New York State pioneered using an inquiry-based test. Part of the test is a practicum. Students have to read instructions and carry out an investigation, collect data, and analyze the data as part of their fourth grade and eighth grade assessments. And very often these children who have been given the opportunity to do science because no one thought they could learn it, actually scored higher in it. That was quite an eye-opener for me.

I also spent some time when I joined the faculty at Brooklyn College looking at the scores of some schools that had been pointed out to me as having adopted NSF-funded curricula and having not just adopted them by buying them but having adopted them by training every teacher to use them and insisting that they were used. In those schools, even though they often had minority student populations of over 95 percent and significant numbers of Title 1 entitled students, those students were performing at the highest level in math, science, and English language arts.

It is not surprising to me. When you get to do science, you have to write about it and you have to talk about it. Your language skills are developed. Your logic skills are developed and you have to use mathematics to do it well. So it is sort of a fundamental way to integrate all of the basic scholarly skills.

I speak, of course, as a scientist, but I believe that scientists also need to write and communicate clearly and, in fact, some of us do not because when we are not trained in an inquiry way and we have to answer multiple choice tests, the way the average undergraduate college science student does, you can graduate without being able to communicate.

So the FOSS and SCIS curricula which were developed actually in the 1970s following the initial push to improve science education in the U.S. during the space race are excellent curricula for getting results, having children learn how to do science.

I have had a situation where two of my students taught the same SCIS lesson to two elementary school classes, one a sixth grade class, one a second grade class, the second grade class had used SCIS since kindergarten and they outperformed the sixth grade class far and away. So the take-home message again is, as Dr. Hill said, you have to do this early. You have to do it often.

Jerome Bruner pointed out to us a long time ago that a spiral curriculum in which children return to key science ideas repeatedly over the years as developmentally appropriate is the best way to build a foundation for advanced science learning in high school and college.

Okay. Unfortunately because these curricula have not been adopted city-wide, we still have a situation where the average middle school student is just not prepared to do inquiry. But, as Dr. Hill said, it is never too late.

STEM CAREER CHOICES

In my own classes for early childhood and childhood education, these are young people that did not decide to be scientists, they decided to be educators, they are afraid of science, they are afraid of math. I can see a transformation in 15 weeks from people who were afraid of science and basically have remembered nothing from their high school careers to people who embrace it as something that they can do and that is worth doing and that they can lead young people in doing.

BREAKING THE CYCLE OF NO INQUIRY

I have seen this. I have been doing this for 16 years. It is not likely to change, but I do know that when these young people go out to the schools, if everyone else is teaching using direct instruction and a textbook, that is what they will do.

So how can we break that cycle? We know what to do. We just do not know how to get it done. The National Science Standards have helped. They have established an understanding throughout the science education community of what best practice looks like. I would like to see that actually—I would like to see it happening in higher education as well. I will hopefully have it when we talk about that later on.

EFFECTS OF NSF FUNDING

But let me say something about what some NSF money has done to Brooklyn College. Funding to my predecessors there for the Brooklyn plan paid for the development of a series of inquiry-based science classes. One of them is called Biology and Chemistry of Every-Day Life. We have one in geophysics. We have one in paleobiology. We have one in environmental science. It gives the students some choice. They take these classes learn to think like scientists.

They also have to take the core classes in gen-ed which are direct instruction. Very often when they come into their inquiry classes, they do not remember much from their direct instruction classes.

We have begun a systematic evaluation program over the last five years where students complete course evaluations on-line and the results for all departments are open to the entire community.

What I found when I took a look at these results was that students who have taken an inquiry-based class answer the question, how much ability to analyze and solve problems have you gained, at a level of about 51 percent saying they have gained a lot. This compares rather unfavorably to the answers of students in geology, physics, chemistry, and biology where one would expect students to learn the ability to analyze and solve problems. In those departments, between 16 and 29 percent as opposed to 51 percent say they gained a lot of the skill. I think this is rather a good indication that the students themselves have realized that they are learning to analyze and solve problems in inquiry-based instruction.

When asked how much ability to find and use information on your own have you gained, we see similar results. Let me see if I have my exact numbers here. Fifty-three percent in general science, and we are talking about 800 to 1,000 students answering this question each semester, compared to 21 and 26 percent of students in traditional science classes. That includes incidentally undergraduate and graduate students in both cases.

So what we see is that what we are trying to do is teach students to think independently and how to solve problems. And they say that that is what we are doing.

In addition, students in these classes say that they have gained a lot of ability to effectively communicate which, of course, teachers need to do, but so do scientists. If scientists are going to be able to get their message across to the American public, they need to be able to communicate clearly.

So we see that more than twice as many students are saying that they have gained a substantial amount of these skills. This happens because their learning is active, not passive. One student said this course is interactive. You do not fall asleep listening to a lecture for three hours. Also you learn better when you are doing science rather than what you call learning about science.

USING LOCAL RESOURCES

I would like to move on to some of the work that we have been doing more recently with graduate students. About ten years ago, I reached out to the American Museum of Natural History. We had a crisis of materials for learning science in New York City. And the American Museum of Natural History has perhaps one of the most amazing collections of real things in the world. It was right there and none of our students were getting to use it to learn. And our teachers, many of whom come from other cities and other countries, were not even aware that it was there.

So I said any teacher educated in New York City should know that this resource is here and know how to use it to teach the young people in our city. And Mertz McDonald, who was then the Director of Professional Development, agreed with me and opened her doors. She agreed to let our teachers come in after the museum was closed and use the halls. And it was quite an amazing experience.

As a result, we developed a course, Science Beyond the Classroom. And as a result of that as well, the Wildlife Conservation Society, also known as the Bronx Zoo, called me and said we would also like to have your teachers come and learn with us.

Similar to our other courses, our students respond that they have gained a lot or a fair amount of ability to solve problems and gain information. In the case of our most recent course with the zoo, the total numbers in those two categories were a hundred percent for both. I think that is sort of exciting.

But what we found out when we evaluated the programs was that principals were not allowing teachers to take their students to the Museum of Natural History or to the zoo. They thought that was not instructional time. That was for June. That was for fun. That was a reward.

Luckily we were able to show the City Council that there was value in this crazy idea of taking kids to the zoo and taking kids to the Museum of Natural History. And they funded a project called Urban Advantage.

Urban Advantage invites teachers to come to seven major institutions in New York for training in how to teach using the resources of these institutions. They include the zoos, the botanical gardens, New York Hall of Science, New York Museum of Natural History, and Staten Island Zoo. We go out to the outer boroughs too.

And what has happened now is the principals have learned that this is actually a good teaching tool. They are getting very good resources. Families have learned that their children are excited about learning at these places. And the culture is beginning slowly to change. So that is very exciting.

I believe that the museum has actually reached out to a few other major cities and some places are talking about doing similar projects. That is moving along. So systemic change is slow.

EXIT PROJECTS AND STUDENT ASSESSMENT

Another very important thing for us was the idea of exit projects. New York City adopted a requirement that every middle school student must complete an exit project either in social science or natural science. The exit project has to be an individual research project. It can use literature research, secondary research, or individual investigation.

For the first year, I must say the results were somewhat disappointing. A panel of scientists did not find them to reflect the processes and procedures and communication methods of science. But with a little feedback, we developed what is called a rubric. I do not know if you are familiar with the idea of a rubric, but it defines what excellent practice looks like for every aspect of a project from the forming of a hypothesis to the collection of data to the literature research to analyzing your results and representing it using graphs and charts as appropriate.

So what we have done is broken down the various skills and said what poor practice looks like, what poor performance looks like, what intermediate level performance and what exemplary performance looks like. It breaks the secret.

There was a time when a good student was a student who knew the secret of what the teacher was looking for. By making the secret open, we make it possible for every student to achieve excellence and students will. Actually, one student commented that with a rubric, you have no excuse for not doing well in a course. So I am excited about that change as well.

NEW COURSE DEVELOPMENT

Our new courses for graduate students have been funded by New York State Education Department and by New York City Department of Education. Over the last three years, we have been training our Earth science teachers, and I should say that this is also with NSF funding, through the geoscience education grant. We received funding to develop a new teacher education program of 30 credits that brings together geoscience and education linking content and pedagogy in every course. This requires, of course, that the Geology Department consider this a priority, and we have been very lucky to find that the Department was willing to be a partner with us.

In one of our first courses, developed with NSF funding, we found that 45 percent of students responded that they had gained a lot of ability to analyze and solve problems as opposed to 16 percent overall for the Geology Department. For 55 percent, they gained a lot of ability to find and use information on their own.

So we have been able to change the culture of graduate study in the Geology Department and, in fact, the Department has received funding through NSF to revise their undergraduate curriculum as well.

So one department at Brooklyn College has said inquiry-based instruction is not just right for K to 12, it is the right way to approach graduate and undergraduate education for teachers and for all of our students.

HIGH-STAKES STANDARDIZED TESTING

Okay. I just want to say a few things about some other barriers to the use of inquiry in K to 12 and that is high-stakes standardized testing.

New York City and New York State have begun to change how they evaluate students, New York City with the eighth grade exit project, New York State with a high-stakes exam that looks at both objective testing as well as a practicum. However, for the most part, these tests are expensive. They are difficult to grade. They require each student's test to be individually graded. And I think that it would be very helpful if we had very good, well-normed tests that actually looked at inquiry-based learning and science process skills as well as the tests that we currently have which are looking at which facts you have memorized. That is the lowest level of knowledge according to Ping's Taxonomy of Learning, the highest level being able to analyze and evaluate material as opposed to just recognizing that it is right.

One method that might be very useful to develop would be an electronic concept mapping assessment. Concept mapping was developed by Novak at Cornell University to look at how students learn biological sciences. It is now used routinely in many classrooms to help students organize their understanding, and there are electronic concept map programs that allow us to see what students can do. It should not be that difficult for a good computer programmer to turn this into a high-quality assessment.

INCREASING UNDERGRADUATE STEM MAJORS

Okay. And one more thing in response to the comments that were made earlier about undergraduate science education. One of the things that we have discovered at Brooklyn College, again with funding from the National Science Foundation through a STEP Grant, we discovered that students who did not think they wanted to be science majors but who were good at science and math as high school students could be redirected to a major in science, including a major in physics, if their freshman year course work was well supported, including social support as well as academic support.

So what we have done is we have created learning communities where students learn about career opportunities in the sciences that they are not aware of as they come into college. And they also work with peers in peer-assisted learning to practice the skills that they need to be successful in their courses.

What we found is that over half of the students who were participants in the freshman year choose a major in one of the STEM fields even though it was not their original intention. We also find that we are retaining virtually all the students who choose a science major. And that is unusual. Usually you lose more than half of students because of the rigors of the freshman year course work that they are not prepared for.

[The information follows:]

Testimony of Eleanor Miele, Ph.D. February 3, 2010

Summary: Over the past twenty years the Brooklyn College School of Education has received funding from the National Science Foundation to "reform" the preparation of science teachers at all levels. Course evaluations show that students of inquiry-based science courses report gaining more ability to analyze and solve problems and to find and use information than students in traditional college science courses. Financial support for teacher preparation, professional development and access to materials of science instruction and for rigorous quantitative evaluation of the efficacy of inquiry-based science instruction is necessary to make inquiry science instruction systemic and a right for all students.

My name is Eleanor Miele and I am the Program Head of Science Education at the School of Education at Brooklyn College of the City University of New York. I am responsible for the undergraduate and graduate programs in elementary, early childhood and middle childhood science education. Brooklyn College is a publicly funded institution of higher education that serves a diverse urban community. I am trained as a traditional scientist with a doctoral degree and post doctoral research experience in molecular biology and genetics. I have 16 years of experience as a teacher of inquiry-based science to urban high school students and 17 years of experience preparing teachers of science to work in New York City schools. My testimony will address several issues in inquiry-based STEM education:

- K-12 Inquiry Science Curriculum
- K-6 Teacher Preparation
- 5-12 Science Teacher Preparation
- Need for Systemic Change

In the early 1900s John Dewey had already challenged the educational community to allow children to construct their own understanding though concrete interactions with materials and defined the essential features of inquiry learning.

> "*Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject-matter.*"[1]

Beginning in the 1960's, with funding from the NSF, science education was "reformed" to incorporate an emphasis on "doing science" in collaborative groups rather than memorizing science as passive receivers of knowledge. Over twenty years ago the Lawrence Hall of Science of the University of California at Berkeley developed the Science Curriculum Improvement Study(SCIS) followed by the Full Option Science System (FOSS) in a collaboration between scientists and educators to create curricula for elementary school students to gain scientific understanding through active inquiry. Extensive research demonstrated the power of these curricula to increase science content knowledge in students from varied socioeconomic groups and in English language learners, but large scale studies often failed to demonstrate significant improvements in science learning.

When I assumed responsibility for science education at Brooklyn College in 1998, the college had recently received funding from NSF to purchase the SCIS and FOSS kits for use in courses in methods of teaching science as part of the *Brooklyn Plan* to reform science instruction for early childhood and elementary teachers. At that time I conducted my own informal investigations into the impact of these curricula on student learning. I reviewed the aggregate scores of students from a selection of public elementary schools in Brooklyn, NY on the NYS Elementary Science Program Evaluation Test (ESPET). This test was one of the first to include evaluation of students' abilities to *do*

[1]Dewey, J. 1910. Science as subject matter and method. Science. 28, 121-127.

science inquiry. I found that schools that reported that they had adopted the NSF-funded SCIS or FOSS curricula had higher scores on the ESPET than similar schools that did not use the inquiry-based curricula. They often also had higher scores on the state mathematics and reading tests despite having high percentages of minority and Title 1 students. Unfortunately, the limited data available at that time precluded a systematic evaluation of the efficacy of the NSF-funded curricula in New York City Schools.

One anecdote illustrates the power of inquiry-based instruction in empowering elementary school students to learn. I asked teachers in a graduate class in science education to pair up and teach the same inquiry-based lesson to their own students and compare the student products. In one pairing, one teacher was teaching a sixth grade class in a parochial school and the other was teaching a second grade class in a public school that had fully implemented the SCIS curriculum. The teachers were shocked at the results. The sixth grade teacher had difficulty just preparing her students to "become scientists" for the day. The work produced by the second grade class was more sophisticated and gave evidence of deeper understanding than that of the sixth grade class. These younger children had already gained the basic skills of inquiry as kindergarten and first graders and thought of themselves as "scientists." The scientific skills and attitudes of objective observation and analysis take time and practice to develop, just like the basic skills of reading and mathematics.

One of my former students recently sent this news from the "front," a Brooklyn Middle School committed to inquiry-based instruction;

> "...our kids are totally unprepared to do inquiry-based science because they do not have the background knowledge, the non-fiction reading ability nor the higher-order thinking skills required to make the connections that we are asking them to make. We are doing inquiry in our school, but it is a long and painful process. BUT, when the kids do come through the process, they are much more engaged and excited by the process of science as something that they can do - not something that has already been done (by old white men)."

The take-home message; teaching inquiry-based science is difficult--but worth the effort and it should begin before middle school.

The FOSS curriculum has recently been adopted by the New York City Department of Education as the approved hands-on science curriculum for elementary schools city-wide. Nevertheless most schools still opt for the traditional text-based approach with "supplemental activities" because of the lower cost and because of teachers' fear of doing science in the classroom. This is however, a time of historic opportunity to systematically examine the effectiveness of the FOSS curriculum, as school systems enter a new age of data transparency.

To teach inquiry science, teachers must be comfortable with their own ability to engage in inquiry. The National Science Education Standards, published by the National Academies Press in 1996 stated that "effective teachers of science create an environment in which they and students *work together as active learners*." According to the *Standards*, "Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry." Science learning experiences for teachers must

- Involve teachers in actively investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings consistent with currently accepted scientific understanding...
- Introduce teachers to scientific literature, media, and technological resources that expand their science knowledge and their ability to access further knowledge..."[2]

As part of the NSF funded *Brooklyn Plan*, faculty in science and science education developed a new series of required inter-disciplinary inquiry-based science courses. Two of these courses are still required of all early childhood and elementary education majors in addition to the general education

[2] 1996. National Academies Press. *National Science Education Standards*, http://www.nsta.org/publications/nses.aspx

science courses required of all Brooklyn College students.

In 2005 Brooklyn College began a new online course evaluation program designed to look closely at student outcomes. The evaluation uses a standard five level Likert scale of responses and allows for student comments. For this hearing I reviewed the course evaluations with a focus on student responses to questions that are indicators of inquiry-skill development. The two questions are

- How much ability to analyze and solve problems have you gained?
- How much ability to find and use information on your own have you gained?

Possible responses are "a lot," "a fair amount," "some," "a little," and "hardly anything." Starting with the assumption that all science courses place a high priority on the ability to analyze and solve problems, I compared the total aggregate student responses for the departments of Biology, Chemistry, Geology and Physics to those for General Science for the Spring 2009 semester.

I found that 51% of students in inquiry-based General Science courses respond that they had gained "a lot" of ability to analyze and solve problems, compared to between 16% and 29% of students in traditional science courses (20% biology, 29% chemistry, 16% geology, 28% physics). When the two "positive" responses are summed for each department the results are equally clear; 69% of physics students, 59% of biology students, 71% of chemistry students, 50% of geology students and 88% of General Science students reported that they gained either "a lot" or "a fair amount" of ability to analyze and solve problems. These data indicate that students perceive that inquiry-based courses are more successful than traditional science instruction in helping them develop analytical skills.

When asked "How much ability to find and use information on your own have you gained?" 53% of General Science students said "a lot," compared to between 21% and 26% of students in other science courses. Skills in independent literature research are essential to scientific research, and once again students in the inquiry-based courses reported gaining more of these inquiry skills.

The ability to effectively communicate is also a fundamental skill for scientists and educators alike. In response to the question "How much ability to express your ideas verbally have you gained from this class?" 50% of General Science students responded "a lot", compared to 18% of Biology, Geology and Physics students and 23% of Chemistry students.

One student recently summed up the value of inquiry-based instruction with this posting, *"This course is interactive, so you don't fall asleep listening to a lecture for 3 hrs. Also, you learn better when you are doing science rather than learning about science."*

Graduates of our childhood education program enter the profession of teaching prepared to think of themselves as problem-solvers and empowered to teach inquiry-based science to children. Graduates of our program are sought out by principals who are committed to inquiry-based science instruction. Over twenty years later, the benefits of the NSF funding for the Brooklyn Plan continue to bear fruit for elementary school teachers and their students.

Over ten years ago I began to reach out to informal science institutions in the City of New York to enter into partnership with Brooklyn College to increase access to high quality materials for science instruction for all New York City schoolchildren. Working with the American Museum of Natural History (AMNH) I developed a new course: Science Beyond the Classroom. Educators at the Bronx Zoo also reached out as a result of my partnership with AMNH and we have developed two courses in collaboration that are offered to graduate and undergraduate students of education. The Wildlife Conservation Society later received funding from NSF CCLI to expand on the undergraduate courses. (In the Fall 2008 course evaluation survey 40% of graduate students taking the WCS course report gaining "a lot" of ability to analyze and solve problems. 60% gained "a lot" of ability to find and use information on their own. 100% gained "a lot" or "a fair amount" of both skills.)

Evaluation of outcomes from the first collaboration with AMNH revealed a fundamental barrier to place-based inquiry instruction in public education. Our evaluation revealed that school principals did not see field trips as "instructional time." They would not allow the teachers we had trained to teach at science-rich sites such as the American Museum of Natural History (AMNH) to use these rich resources to teach their students. They viewed field trips as rewards, not as educational opportunities.

Synergistically this coincided with the New York City Department of Education implementing a required inquiry-based Exit Project for graduation from middle school. The American Museum of Natural History was able to organize nine science-rich institutions in the city to demonstrate that they could support the Exit Project effort, and with funding from the City Council in 2005 the Urban Advantage project was born. Urban Advantage is a standards-based partnership program designed to improve students' understanding of scientific inquiry through collaborations between urban public school systems and science cultural institutions that has allowed place-based science investigation to flourish in New York City middle schools.

While our partners at the American Museum of Natural History worked successfully to change the system to support inquiry learning at science cultural institutions, my colleagues in the Geology department at Brooklyn College and I worked to change the college to support inquiry learning for science teachers. Bringing inquiry approaches to secondary school teachers is problematic, since their science instruction is typically conducted in science departments which have not embraced inquiry approaches to instruction. Teachers teach as they have been taught. Another problem in effective inquiry instruction is access to materials to observe and manipulate. During successive budget crises, access to materials of science instruction has often been limited in New York City schools. By designing new courses for our graduate programs in middle childhood and secondary science education in partnership with informal science partners, we were able address these two critical problems at the same time.

We began in partnership with the AMNH and our sister college Lehman College to create TRUST, Teacher Renewal for Urban Science Teachers. Together we developed a program including new inquiry-based geoscience courses at the two partner colleges and a summer institute at the AMNH that would count as graduate credit toward teacher certification. Our external evaluator found that 87% of TRUST participants reported that they had taken their students outside the classroom for instruction.

The new course developed at Brooklyn College, Geology 613: Earth Science in the NYC Urban Environment, requires four field trips and is described as follows:

Investigation of five guiding questions regarding the connections between geology and New York City: On what is the city built? Of what is the city built? How has the New York City environment changed? Why did the metropolis develop here? What environmental hazards does New York City face? Mandatory weekend field trips within Manhattan and Brooklyn.

In the Spring 2009 offering of this course, 60% of participants responded that they had gained "a lot" of general knowledge about the subject. 45% responded that they had gained "a lot" of ability to analyze and solve problems. And 55% said they had gained "a lot" of ability to find and use information on your own. Compare these results to the results for the Geology department as a whole, which had the lowest average scores for these questions of all science departments.

Based upon the success of the TRUST project we received funding from the NSF Geosciences division for *Science and the City*, a plan to develop a new 30-credit program of inquiry and field based courses in geoscience for teachers of Earth Science. Our goal was to create an entirely new approach to science teacher preparation using a City-as-Lab approach to produce graduates who are able to integrate the resources of the city into their teaching.

This program includes twenty-four credits in geology that model active learning pedagogies. The courses are thematic in nature and focus on core knowledge from the New York State Core Curriculum in science with an emphasis on inquiry-based learning. The courses were designed by a team consisting of members of the Division of Science of the New York City Department of Education, experienced middle and high-school earth science teachers, informal science educators and college faculty in geology and education.

All course assignments are based on goals that are student–centered, concrete, measurable, and develop higher-order thinking skills by providing practice in key content and process skills through activities and assignments in real world applications. Course assignments in all courses require teachers to create age-appropriate learning activities for students utilizing NYC and NYS cultural and/or natural resources.

During the summers of 2007 and 2008 the New York State Education Department funded a summer science institute, New York City Earth Science & Technology which allowed us to pilot two new courses each summer without cost to the teachers. To evaluate the effectiveness of this summer institute we conducted a program evaluation..

In summer 2007 the content knowledge gain of the participating teachers was assessed by a program evaluator (not the course instructor) using a pre-test/post-test comparison based upon the New York State Regents examination in Earth Science. We found this approach to provide limited data on knowledge acquired. For 2008 we used an open-ended assessment embedded in the first and last course sessions. Students completed a concept map of their current understanding of the main theme of the course on day one and the final session. Concept Mapping, developed initially by Joseph Novak at Cornell University in the course of research to follow and understand changes in children's knowledge of science, is now widely used to organize and represent knowledge. Post course concept maps showed gains in the number of concepts and connections. There were also fewer misconceptions on post-test concept maps.

For all courses, the pedagogic skills of course participants were also assessed by an external review of unit and lesson plans prepared as major course assignments. All lessons prepared by course participants were found by external reviewers (New York City Earth Science Teachers) to be standards-based and inquiry-based. Privacy and union regulations have precluded meaningful assessment of impacts on student learning in New York City classrooms, but new agreements for data sharing indicate that it may soon be possible to obtain data on the impact of inquiry-based teaching in classrooms.

New York City schools face a critical lack of earth science teachers and a high attrition rate of new teachers. At the outset of this project only 7% of the certified science teachers in the city were certified to teach Earth Science. Based on the recommendations of our colleagues in the NYC DOE who assisted us in design of this new inquiry-based masters program, for the past three years, the New York City Department of Education has funded a cohort of NYC Earth Science Immersion Teaching Fellows at Brooklyn College. Over 90% of these Fellows are successfully teaching Earth Science in New York City public schools.

Needs:

In order to systematically institutionalize inquiry-based science instruction, it is essential to support changes system-wide that will support higher order learning and discourage mere memorization and recall. Most current methods of assessment discourage inquiry-based instruction. Development of a digital assessment system based on concept maps would be a benefit to inquiry-based instruction since software for concept mapping is widely available and used. We need to continue to support inquiry-based teacher preparation and professional development and provide ongoing funding for materials of instruction. True systemic change requires additional support for pure research in science education and cognition in science learning. Funding to support the professional education of researchers in science education is also needed to properly document the efficacy of inquiry-based instruction. Properly trained evaluators who understand both science and pedagogy are rare. It is 100 years after John Dewey first introduced the idea of "progressive" inquiry-based instruction. It is time that it was the norm and not the exception, a right and not a privilege.

Mr. MOLLOHAN. Well, thank you both.

Dr. Hill, why don't you bring that back?

Dr. HILL. Okay.

Mr. MOLLOHAN. Is this just absolutely not working? It sounds like it might be.

Dr. HILL. It probably needs to be closer.

Dr. MIELE. Can you hear? No, it is not working.

Mr. MOLLOHAN. Okay. Well, we are not far apart, but we need it. Is it working? Okay. If you speak closely. And, unfortunately, this is so tight that it cannot—okay. I hate fighting with this.

COGNITIVE TRAINING

But, Dr. Hill, you talked about a reference, cognitive training.

Dr. HILL. Right.

Mr. MOLLOHAN. I would like for you just to talk about that a bit for the Committee, give us a better understanding of what cognitive training is——

Dr. HILL. Okay.

Mr. MOLLOHAN [continuing]. And how it——

Dr. HILL. And I also would like to contrast that with tutoring which is the usual approach to, you know, remediating things like math skills.

So cognitive training, first of all, is not instruction. It is actually trying to build the underlying cognitive architecture in the student, so you can take a task, there is a famous task in experimental psychology called the Stroop Task where you have letters, I mean, I am sorry, words that spell out color names, but the ink of the color could either match the color name or could be incongruous with the color name.

You can use that kind of task to teach attention. They have to attend to either the color of the ink or what the word is saying. You can use that task to train processing speed because as they master a certain skill level, you can cause them to do it in a shorter amount of time.

And so you can take any kind of task like that and use it to train processing speed, memory. You can give them distracter tasks. They have to now have divided attention, sustained attention, selective attention.

But basically what we are talking about is building the underlying structures of cognition that then allow you to have kind of a framework to place abstract concepts like higher level mathematics, for example, or even processes like critical thinking skills. It is like you need some basic architecture underlying that in order for it to work.

And this is kind of an innovative approach, but when I first encountered the data from this Learning RX organization, I was just stunned at the kind of changes they were getting in 15 weeks. You mentioned 15 weeks too. That seems to be kind of an interesting number.

But what we are looking at is the transfer that this kind of training has to things like learning math. And we are finding that even measured with imperfect measures like the standards of learning test in Virginia that we get tremendous increases after one semester of these kinds of interventions.

Now, the problem is in the past, these kinds of interventions have been one-on-one, kind of in a clinical setting almost. And so we are trying to find ways to broaden that so that you can have group administration on a computer that is not going to be as efficacious, but we want to see if it is good enough, you know, if we can still get some significant results with that because that would be much more practical in an educational setting.

Mr. MOLLOHAN. Intervention sounds like a remedial process. Does cognitive training happen the way you think it should happen and when you think it should happen?

Dr. HILL. Well, it is remedial in the sense that I guess if a person grew up in an enriched environment where they were in a home where there were many books around and they were having conversations with their parents, these kinds of cognitive skills would tend to develop naturally.

You are talking about kids who come from homes where there might be one or no parents around, where their nutrition is inadequate, they get no stimulation, no supervision sometimes, and so they are not developing these kinds of skills.

Mr. MOLLOHAN. Yes. What I heard you saying is that the examples that you were alluding to happened after a period of time when it would have been good to lay this cognitive foundation, this framework that you are talking about.

And so what I am really asking is, how should it happen, unless I am misunderstanding what you said——

Dr. HILL. Well——

Mr. MOLLOHAN [continuing]. How should it happen in the normal educational process and when?

Dr. HILL. Well, normally these kinds of processes would not be directly dealt with in education other than in the kind of inquiry-based learning that we just heard about, which do tend to develop thinking skills.

But what we are saying is that if these skills are not there, it is not that there is some critical period that they have to be developed. And even in adulthood, you can start to train these skills and get those kinds of results.

So this has been very encouraging that even if a kid comes from an impoverished and stimulus-poor environment that at the middle school level or at the high school level, it is not too late to have these kind of interventions.

Mr. MOLLOHAN. And that is what I meant when I said that it sounded like you were describing a remedial process. And by that, I meant a process of intervening at a later time in the educational process and just forgetting for a second what socioeconomic background somebody comes from.

Dr. HILL. Right.

Mr. MOLLOHAN. Are you suggesting that the educational system should be laying that framework down in the educational process at some point——

Dr. HILL. Yes, from the beginning.

Mr. MOLLOHAN [continuing]. In a child's development? Okay.

Dr. HILL. These kind of inquiry-based methods of instruction.

Mr. MOLLOHAN. And, I mean, we are talking pre-K?

Dr. HILL. Pre-K.

Mr. MOLLOHAN. We are talking kindergarten, we are talking——

Dr. HILL. Yes.

Mr. MOLLOHAN. Okay. Is that happening——

Dr. HILL. No.

Mr. MOLLOHAN [continuing]. Anywhere?

Dr. HILL. Well, apparently it is happening some places. In Brooklyn, yes. But in general, and can I just piggyback on what was said about these high-stakes standardized tests, in Petersburg, for example, where you have a distressed district that has a hard time holding on to good teachers, these are just deadly. Their whole day is spent teaching to the test. I mean, it is deadly for the teachers. It is deadly for the students. And it does not have the outcomes that we——

Mr. MOLLOHAN. Well, I really think we are convinced that there is a problem seriously, I mean, based on this testimony and, you know, what we hear.

Dr. HILL. Yes.

THE SUPERIORITY OF INQUIRY-BASED INSTRUCTION

Mr. MOLLOHAN. But let me ask, Dr. Miele, is there any real debate about the advantages, the superiority, if you will, of inquiry-based STEM education as opposed to direct fact learning? Is there any real debate about that?

Dr. MIELE. There is no debate. The consensus of the science education community is this is the right way to teach young people.

WHO MAKES STEM EDUCATION CHOICES?

Mr. MOLLOHAN. Then why is it not being readily accepted and hearing you all testify here today, it is apparent it is not systemically embraced?

Dr. MIELE. Because the choices are not made by the people who are in the science education community. The choices are made by generalists in grades one through six. Principals are typically not science educators. They are typically more likely language arts. Actually, we get a lot of people from the humanities. I am not knocking the humanities. They are great. Those people are not aware of the special needs of education in the sciences and in mathematics, but they are making the choices of curriculum.

Mr. MOLLOHAN. So the obvious question is, how is this overcome? I mean, if it is consensus among the people who should know, but there is this impediment to mainstreaming this kind of education in math, science, how is that overcome in the real world?

Dr. MIELE. One step is to make sure that the standardized tests test those skills so that the principals know that their students have to learn them.

Another way is to make sure that some funding for schools has to go not to textbooks but to consumable materials for learning science. If it was earmarked in the budget that the only thing you can spend this money on is either a kit or your own materials purchased and demonstrated to be appropriate for teaching hands-on science, and that might just be, you know, vinegar, baking soda, and plastic cups, frankly, it does not have to be a sophisticated kit, it just has to be the things that have been shown for the last 50 to 100 years to be effective. If you have to spend some of your money on consumables, you have to be doing science.

EFFECTIVE, ACCELERATED IMPLEMENTATION

Mr. MOLLOHAN. Okay. Well, we are in the business here of funding worthy programs in a very competitive way. We could fund these demonstration projects and the STEM education grant that you got from NSF which comes from this Subcommittee all day long, and if you did it on a grant-by-grant basis around the country, it would be our great, great, great, great grandchildren by the time it got down to them.

How does this form of education become the accepted model and in that way be adapted by educational institutions from K through graduate school in a far more expeditious way? How does that happen? Do you need a definitive study from NSF or from the National Academy or what? And so we have those?

Dr. MIELE. You know, at this point, many of the studies show mixed results. And it is my belief that the reason they showed mixed results is that just because you bought an NSF-funded curriculum does not mean that your teacher used it or used it properly. So you do need truly systemic change, but you also need the high-stakes test to match. And we have never had that congruence where the high-stakes test was, in fact, one that looked at inquiry skills and at the same time, you had an entire discernible region that really implemented it.

If we could have that, it would be helpful. I do think that we need more people to be trained as evaluators. There is a dearth of high-quality educational evaluators who also understand science. So that would probably be helpful.

We also need to train the teachers that are veteran teachers because our young people coming out know how to do inquiry science. I have yet to meet a science educator who does not teach inquiry. It is the consensus, but they get out to the schools and all of a sudden, it is not what is happening.

It is generally believed that you need a minimum of 60 hours of high-quality professional development that is truly inquiry based with a facilitator who can help you make the transformation and a principal who will let you do it.

Mr. MOLLOHAN. Okay.

Dr. HILL. Can I add to that also?

Mr. MOLLOHAN. Certainly.

Dr. HILL. I mean, if you look around the country at the schools that are succeeding, they are the ones that have some degree of independence, you know, usually a charter school or some other mechanism they have had to extricate themselves from the educational bureaucracy so that they can try innovative kinds of things.

And just to put in a word for the humanities, I do think that, you know, in many of these inner city schools, we have kind of almost eliminated the humanities, you know, things like music, language. Those kinds of exposures at an early age can also have transfer to the kinds of critical thinking skills that we are talking about at the middle school and high school level.

And so part of this is budgetary. You know, good education is expensive. And so we are cutting corners wherever we can. We are trying to stick to the basics, so to speak, which usually means teaching to the test. And it is just a complete mind set that has to change.

Mr. MOLLOHAN. And that is why I am suggesting you need some seminal study that——

Dr. HILL. Right.

Mr. MOLLOHAN. [continuing]. No one can deny the validity of and that everybody has to respect and then adopt it. And that is really what I was kind of——

Dr. HILL. I mean, if you could find a superintendent at a major city that would be willing to, you know, implement this evidence-based practice throughout the system and, you know, it could be your hard case like, you know, in places like New York City, Chicago, Los Angeles and demonstrate its efficacy in that environment, I think that would be very convincing in other parts of the country.

Mr. MOLLOHAN. You need a good model.

Let me call on——

Mr. WOLF. Thank you, Mr. Chairman.

INDIVIDUAL SUCCESSES AND PERVASIVE PROBLEMS

I have some questions. Maybe we will just submit them for the record and just ask you, I mean, have we not really done all of this, though? I mean, this country is 230 years old. We had the best educational system in the world. And now when you look at the scores, and I have not looked at them for the last couple months, the figures, but we were like 21st or 22nd in math.

We have so many individual successes around the country, but overall there is the problem. And I think, and I do not know that it is just necessary funding, it is an attitude and there is something wrong. There is something going on that, you know, why are the young people here not as interested or scoring as high as they are in China or as in Singapore.

The purpose of the amendment that we offered last year to the National Science Foundation is we should know what the best practices are now and have every school system in the country adopt whatever these best practices are because we have been operating. We have a broad foundation. We have all these different groups doing all these studies and research and putting a lot of money. And we have the Gates Foundation doing all of this.

So I would think that we would know now what works and what does not work. The question is getting the localities to implement and also doing something to make the young people have an excitement about math and science and physics and chemistry and biology and different things like that.

But why do you think we have fallen behind?

TEACHER TALENT

Dr. HILL. Can I address that? I think the teacher variable is one thing. I mean, for decades, if not centuries, in this country, we had a free ride because the best and brightest women would go into education because that was the only field available to them. And when opportunities opened up for women, we did not replace them in the classroom. We did not raise the salaries to attract the best and brightest. We did not raise the prestige level of teachers.

And so now it is a hard sell to get the best and brightest to go into the classroom. And no matter how good the methods are, no matter how good the curriculum is, if the teacher is not excited about knowledge, if the teacher is not knowledgeable in their subject matter, it is going to be hard for them to convey that to their students.

So we have to find a way to get the best and brightest again attracted into the field of education.

REWARD OF STEM CAREERS

Dr. MIELE. And I concur 100 percent, but I would like to add that we also have to get the message out that careers in science are exciting. As I said, when we showed freshman what you can do with a science major, they were shocked. They had no idea. They thought they had to wear a white coat and be in a lab.

But there are many, many careers that are based on a sound technology or science major, including careers in law, environmental law, for instance, medicine. I mean, there is quite a long list. And when they go out and interview people who did majors in physics and chemistry and find out that some of them are entrepreneurs starting green businesses, they say, oh, I could see myself doing that and suddenly they want to major in science.

But what the message has been to the generations for the past, I would say, 20 or 30 years of young people who are thinking about science is you are going to have to become a lab coat scientist or you might as well, you know, go to Wall Street or become a lawyer straight, you know, straight from a liberal arts background.

And we do not actually reward our scientists very well.

Dr. HILL. And if I can add to that, too. Making them aware of the possibilities in terms of salary. I mean, business schools are bulging in most universities because kids have the idea if you get a business degree, you are going to do pretty well salary-wise in your career.

So I do think it is a matter of getting the information out, getting the word out.

Dr. MIELE. They want to go to medical school. They do not realize that they can do well by doing science.

Mr. WOLF. Okay. Well, you know, we can talk about this forever. I remember the movie I saw of the young boy from West Virginia, October Sky, and I just think there is something missing. There is something wrong.

DECLINE IN U.S. MANUFACTURING

And, you know, I think the real danger is, and I think we could be approaching the point, is that the fewer manufacturing and fewer things we do in this country, even if you then create an interest in young people, there will be no place to go.

If you get on the train in Washington and take it up to New York City, if you do not read your book, you just look out the windows, the factories are closed. You go through my old neighborhood. We had the largest General Electric factory I think in the world. It is gone. It is all gone.

And if you no longer have the manufacturing base and opportunities, then it will almost become a self-fulfilling prophecy because I think some of the young people believe that there will not be the jobs even if they get in it.

GOOD STEM EDUCATION

So I think, you know, the time is now. I think we should have enough information. My sense is you have to deal with it in K through six. If you lose somebody after sixth grade, maybe it is fifth grade, maybe it is seventh grade, you are not going to find them again.

In my area, we have Thomas Jefferson High School, one of the best high schools in the country. These kids are creative. They are anxious. They are interested. I think we should be able to replicate that all over.

But, anyway, I appreciate your testimony. There is something wrong. Anyway, thank you so much.

Dr. HILL. Thank you.

Mr. WOLF. Mr. Chairman, I would like to submit the questions, if I can, for the record, please.

Mr. MOLLOHAN. Certainly.

Dr. HILL. Mr. Chairman, can I make one other comment about funding?

Mr. MOLLOHAN. Certainly.

CHALLENGES FOR YOUNG FACULTY AT HBCUS

Dr. HILL. Since you mentioned it, you know, this Committee, that is one of their charges is to go through agencies like NSF and NIH to get the funds out there. If we could have some new models of funding like I was mentioning earlier for faculty at places like HBCUs that do not have the traditional steps for acquiring funding because even when NSF has an HBCU initiative, the issue is on the other end, on the faculty member having the time to write a competitive proposal. And that is why sometimes a lot of money stays on the shelf that, you know, could be accessible.

So if we could think of things like research initiation grants where we are giving money directly to HBCUs to fund their faculty research, to give them the time, those are where the bodies are, the roles models.

And, again, we have an engineering school that takes in three or four hundred kids every fall and we lose two or three hundred of them.

Mr. MOLLOHAN. Well, maybe some of the other members want to talk about that, and then we can talk about it when it becomes my turn again.

Dr. HILL. Okay.

Mr. MOLLOHAN. Mr. Bonner.

Mr. BONNER. Thank you, Mr. Chairman, for once again leading the full Committee by coming out of the gate with the first, to my knowledge, the first hearing. The President's budget has not even dried yet and we already are like we did last year into asking some good questions of bright panelists.

Thank you both for being here.

MATH SCIENCE HIGH SCHOOL

There are so many things, and I, too, would like to submit my written questions for the record for your consideration, but there are just so many things going through my mind.

Last week, I taught at Alabama School for Math and Science. I am from Mobile, Alabama. And our State School for Math and Science, which is a residential campus, is in my hometown of Mobile. I did not teach math or science. I taught a class on American civics.

And the graduates from that school have an opportunity to go to MIT and Stanford and Harvard and some of the finest schools in America with full-ride scholarships. So it is something we are very proud of.

STEM EDUCATION IN RURAL AMERICA

And, yet, I am from a town of 1,200 people in the most rural part of Alabama, and I know there are rural parts of West Virginia and there are even rural parts of New York, Chairman Serrano, but I worry about science education, math education in rural towns because the town I grew up in, I was blessed. I had a very good math and science teacher that loved it, knew it, and shared it.

But in listening to the story of Brooklyn or what is going on in our larger cities, I do worry what can we do about making sure that our rural educators and our rural science and math curriculums are not being left out because everyone cannot travel to the zoo and have an up close and personal experience. Again, we have got a science explorium in Mobile. We have got a lot of things that a lot of other cities, communities do not have.

What do we need to do to make sure we do not forget about the rural schools in America?

Dr. MIELE. I would say that the rural schools have things that New Yorkers do not have. Those young people actually know what a cow looks like. You know, every community has its strengths and the real thing, the world is there for all students if they have educators that know how to help them look at it objectively, systematically, and to think about how the world works.

I really do not think that that is the issue. I would love to be able to bring our students, you know, to nature. And for us, all of our nature is highly degraded. I mean, we go and look at a forest and it is trampled by millions of feet. And the only kinds of animals you see are squirrels and maybe rats.

I think the issue really is when we talk about good science, it is about process. And if you have learned to think like a scientist by the time you are 12, you will be able to learn in the formal way, what we call the direct instruction. It is not difficult to learn new material once you have learned to think like a scientist. But if you had not learned to think like a scientist and you have not valued that whole approach to knowing the world, then those doors are completely closed to you and you are basically thinking magically the way a three or four-year-old would even if you are 35 or 50 or 60.

EIGHTH GRADE EXIT PROJECTS

Mr. BONNER. Well, Dr. Miele, let me mention or ask you to elaborate. You mentioned in your testimony here something about the eighth grade exit project.

Dr. MIELE. Yes.

Mr. BONNER. My daughter is in the eighth grade. I hope she exits the eighth grade. Tell me a little bit about what you were talking about in greater detail.

Dr. MIELE. I believe it was five years ago, we had—New York City, as you know, is big. You know, we have got a million school children. Actually, I think it is 1.1 right now. And we had local control. So every community school district chose its own curriculum, chose its own assessments. The only commonality was the State Regents examinations and periodic tests, standardized tests just for promotion.

But New York City decided that they wanted to do something to enforce learning in an inquiry way, so they said, okay, we want to make sure our children can think independently and logically and the place to look for it is eighth grade on the doorway to high school.

So they instituted the requirement that every student had to complete an independent study and it could be in social science or it could be in natural science. It had to be one or the other, and it required that they formulate a question and figure out how to answer it. They could choose to answer it by using literature resources, but they needed to be valid literature resources. They could not just take the answers from Wikipedia, for instance, and they needed to document what their sources were and why they chose them. And they needed to complete usually a tri-fold panel for the equivalent of a science or social science fair and to defend their work in front of their peers, teachers, parents, and visitors.

As I said, the first year we really did not know what to look for. There was no clear criterion for what excellence looked like. But the city decided to bring together a panel of scientists and social scientists to provide feedback about what exemplary exit projects would look like.

And they developed a very extensive rubric to support the students and also a multi-step sort of guide to help them figure out what do I do first, what is a reasonable question to ask, how do I know it is a good question, what is my first step in finding information, where can I go for data if I want to do secondary research where I am using a data set that someone else has collected, but I want to ask my own question about it.

For instance, the GLOBE Program provides databases that students can access. Maybe they will take some data from GLOBE and maybe they will collect some of their own data and do a comparison.

So these are the kinds of projects that students are doing in New York, and they cannot get into high school without having thought for themselves deeply at least once.

Mr. BONNER. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Bonner.

Mr. Serrano.

Mr. SERRANO. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Who probably knows something about New York education.

CHARTER SCHOOLS

Mr. SERRANO. A little bit. Thank you again, as Mr. Bonner said, for leading us out of the box with the first hearing, especially during what Washington would consider a blizzard. So it is quite an accomplishment.

Mr. MOLLOHAN. That is a testament to our witnesses.

Mr. SERRANO. That is right.

Since you have mentioned it, let me just quickly, before I ask a couple of questions, including one that comes to mind that I did not have planned, talk a little bit about my background. Prior to my 20 years in Congress, I was Chairman of the Education Committee of the State Assembly. Prior to that, I was everything within the school system except a teacher. I was a paraprofessional teacher's aide. I was Director of the Title 1 programs at the State Urban Education Program.

So I have a little bit of a background in that area which leads me to this question. There is a lot of press, good press for charter schools. And I may be the only elected official in New York State that has not signed up making glowing statements about charter schools.

And while I understand their success and support their success, my fear continues to be that it is just part of an excuse not to attack problems of the public school system and that charter schools may become what we, some people who support public education, have always attacked in the parochial school, in the private school system, which is you will be able to take the better students, show better results, and leave behind in public schools those that are weak, with parents who are not as mobilized as the ones in the charter schools.

So you see, for instance, in New York City, whether what side you fall or not, you see the Mayor closing down 19 schools and then upping the amount of charter schools available in the city. And we have not figured out yet if that is really a way of just turning your back on the public schools.

So my question is, have we reached the point, especially in the inner cities, where it is save yourself if you can and, therefore, charter schools serve that purpose and do we run the risk of turning our backs politically and otherwise to the public school system more than ever so before? What is the future of the public school system in this country if we continue to grow charter schools, to both of you?

Dr. HILL. Well, if I can address that a minute, I think one of the roles of charter schools now is to be innovative and to test some things that might not have been able to be instituted in the public schools, the normal public schools.

I think you raised a big issue and I think this goes back to what I was saying earlier about the need to think of education as a civil right. Somehow we have said it is okay for there to be Thomas and Maggie Walker Schools in Richmond that offer excellent education, but they are not for all kids and that it is okay for the kids in the inner city to just to get by with whatever the basics are.

We need to change that mentality and recognize. I mean, we need to think of it in terms of our own self interest, that it is not the other kids, the other people's kids are the ones that are involved here. This is going to be something that impacts us as a nation and get our self interest involved in seeing schools transformed in general.

And a lot of times to do that, I mean, Richmond, Virginia is a good example, I mean, go back to 1954 when the Brown Decision came, you had the school issues were along racial lines, you know, in terms of resources. They are separate but equal, so to speak.

Over the years, that what started out as a racial issue, you know, merged with class and other issues and so now it is a much more complex problem, but it has its roots back in the days of segregation where it was okay for some kids to get a quality education and some kids not to get a quality education.

We have to find a way to get beyond that and maybe it takes shame. You know, we should be ashamed as a country that we have allowed this to go on for 50 years. And we need to take the hard fixes and not necessarily the easy fixes.

A lot of times when we find, for example, the minority kids are not passing a particular test, we attack the test rather than dealing with, well, why are they not passing that test. Why do we not put the resources in there. And the rural kids, the same issue in rural communities.

But I think the distrust of charter schools among those of us who kind of grew up in the civil rights era was a remnant of the time when public money was going to provide education and private academies and the inner city kids were being left behind.

But I think we have gotten to the point now where we have to think outside the box. We have to revolutionize our whole educational system. The whole model needs to change. I mean, it is kind of an industrial age model, and we need to have innovation. We need to have creativity. We need to free up principals and teachers to try innovations and then use evidence-based practices wherever we can.

That was kind of a round-about answer.

Dr. MIELE. I have a few things to say about that as well.

I think it is a very sad situation right now that the schools, many of the schools that are closing have parents that support them. And this to me is a disconnect. When the parents are involved enough to know what is going on in the school and care enough to come out and say do not close my school, then it is not an issue of the parents that do not care. So there is definitely something going on here.

There are a number of things going on in New York City schools. For the past, I think it is probably about 15 years, the reading programs, for instance, have focused entirely on poetry and fiction. Students are not really learning to read content. This is one of the reasons they come to middle school unable to read a textbook.

By middle school, as much as I support inquiry education, students should be able to read a textbook. By the time they are 13 years old, it should not be too hard for them, but that is the situation that we have because the skills they are developing are not giving them the ability to read content objectively, to read it critically, to read it deeply, to understand what are the facts, what are the opinions, what is the evidence that supports these assertions.

There is no system that allows students and parents to really truthfully say what are the strengths and weaknesses of the school. They know. My own children went to New York City public schools and there were good years and there were bad years. And we were committed to public education and we rode out the bad years and did what we could to ameliorate what educational weaknesses there were.

But my husband and I are college educated and we are educators and we could do that easily. It is, in fact, an equity issue. There is no way that an immigrant family working two jobs, even if they love their children and want the best for them and try to help them with their homework, can provide what college educated Americans can provide. It is impossible.

So, yes, the issue, I think, is how can we make all public schools truly provide a quality education for all students and not go around—and, by the way, the charter schools are inequitable to teachers as well. They do not pay them as well.

Dr. HILL. Right.

Dr. MIELE. They will hire people who are not certified and make use of the fact that they are bright and committed and caring and willing to share apartments.

So what I would like to see is more money going, as I said earlier, to making sure that there are materials of instruction and money going directly to the schools for high-quality professional development to teach them to teach with the best practices if they are not yet prepared to do that and something that will hold principals accountable for best practice in every discipline, not just the one that they were trained in.

Mr. SERRANO. You know, one of my fears—do I have time, Mr. Chairman?

Mr. MOLLOHAN. Yes.

Mr. SERRANO. One of my fears is, and I do not know if it is the same in other districts, I am sure it is if we look closely. I get people coming to me, I need a letter of support, I want to open up a charter school. I do not give those letters of support out. But I say what do you know about schools. And they are usually very active community leaders who may be great on some issues, but what do they know about schools?

But under the charter school system, I can open up a charter school tomorrow if I get okayed. And if I left Congress, I probably would be okayed to open up like ten charter schools. Well, I may have the best intentions at heart and I probably have a little more background than some other folks, but what qualifies me to open up a charter school?

Then the argument we hear, which is a solid argument, but I think it does not speak to this point, is, well, when we had all the schools run by people college trained and professionally trained to be teachers, administrators, they did not do the job. So let us try it now.

But I see it almost like it has become a business for some people, the charter school, either a business for the position they hold and so on. So I am still out there like a sore thumb, you know, standing out in the community being like the only—I am also the only guy saying New York should hold those terror trials, but that is me, you know, I do not always go with the flow, but—so that is a concern.

Now, my last question, which was the one I did have written down, kind of ties into that when you spoke about the immigrant parents and so on.

ENGLISH AS A SECOND LANGUAGE

In your studies, Dr. Hill, and I want you to comment on this, too, the fact that some children have a language other than English at home and, therefore, may or may not be totally proficient in English in school, does that add to the mix once again as it supposedly did in the past?

Now, I had people who spoke only Spanish at home and that was not an issue in the 1950s and in the 1960s. It became an issue in the 1970s and then it seems to be an issue again. Do you find that that is an impediment? What is that situation when a child in class dealing with the sciences now, math and science, with another language being spoken at home?

Dr. HILL. I mean, math and science is hard enough when it is taught in your native language, you know, much less when it is a second language. But, yes, certainly that is an issue. I mean, there are so many kinds of noninstructional issues that come to bear here.

EFFECTS OF POVERTY ON EDUCATION

I mean, when you look at a school district like Petersburg, again, how many of those kids come to school with no breakfast, with no parent, out all night, dealing with maybe a drug addiction in the household, dealing with parents who are incarcerated? There are so many issues that are beyond the scope of the teacher, you know, what the teacher can deal with there.

BUILDING STUDENT SUPPORT

So one of the things that we are doing in Petersburg with this approach with the algebra project is building community support mechanisms for the schools because a lot of times, the kids need, they need good instruction, but they need other things as well. They need other kinds of social support in addition to instructional support.

And so having those available to the kids in some kind of systematic way is an important thing. Mentoring is important. Having the kid connected with somebody that they can talk to, whether it is a college student, whether it is an older high school student for a middle school kid, but having somebody they can make that connection to that they might not have with family members, and then counteracting the effect of violence.

I mean, we are looking at some neurological studies now about the impact on the brain of exposure to violence and it actually, if your brain is affected, it is going to impact how well you take in information. And so having some interventions for those kids who are the victims of violence both at home and the kind of violence that they might see in the street or even in the schools in many cases, so it is like an omnibus of needs that are there that need to be addressed with these kids.

Mr. SERRANO. Omnibus is a very tough word to use, you know, before the appropriations committee. It brings pain up our back.

INQUIRY-BASED INSTRUCTION AND ENGLISH SKILLS

Dr. MIELE. The NSF funded SCIS and FOSS curricula had shown tremendous ability to improve English language learner scores when they were studied in the 1970s in the LA area. And from my own experience, many of my students are themselves, even though they are college students, are English language learners.

When you are working with the real world and your job is to observe it objectively, it speaks to you in whatever is your language. So that is not a barrier; a textbook does not do that. So if your main source of information about science is a textbook and you are a fourth-grader from Bangladesh, then you are basically shut out entirely. But if you are looking at what objects sink and what objects float and you are measuring their mass and volume for yourself, then you have learned the material for the day. And you may not be able to write it down so that your teacher can understand it, but you have written it down so that you can.

So hands-on science absolutely brings in everyone regardless of whether they are an English language learner or whether they are English proficient.

Mr. SERRANO. Thank you.

Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Jose.

Mr. Ruppersberger.

Mr. RUPPERSBERGER. Well, thank you. I am sorry I was in another hearing. Do I need this? Is it too loud?

Mr. MOLLOHAN. You need to use it.

NATIONAL SECURITY AND PRODUCTION OF STEM PROFESSIONALS

Mr. RUPPERSBERGER. Okay. First thing, let me tell you where I am coming from with my questioning. I serve on the Intelligence Committee and Chair the Technical Tactical Committee dealing with cyber security and a lot of the issues involving science.

One of our concerns from a national security point of view is that China last year graduated over 660,000 mathematicians, scientists, and engineers. And I think we, the United States, graduated about 66,000.

Now, the good news, our curriculum still seems to be superior, but China is gaining very quickly.

Now, in preparing for this hearing and looking at where you are coming from, both Dr. Hill and Miele—is it Miele?

Dr. MIELE. Miele.

HOW CAN WE BRING ABOUT CHANGE

Mr. RUPPERSBERGER. Miele, okay. You are emphasizing that we need to change the way we teach science and I agree with you. You are advocating for moving away from memorizing facts and figures and moving towards more hands-on learning and more accurately learning that engages the student to be more inquisitive. I think inquisitive is what you were just really talking about.

My issue is why have we not moved more towards the direction of your philosophy and the STEM schools? Is it lack of resources, equipment? Is it lack of knowledge on the part of our administrators or people who fund schools which would be elected officials? And, you know, we need to address that issue first.

And how we do address it, I think we need to educate those decision makers why science is so important. I will say this. I know that some of our military academies from the year about 2013 or whatever will try to have over 70 percent of their graduates having STEM education because this is where our country is going, not only just in national security, but just what we do every day.

Dr. MIELE. I mentioned earlier that the problem is the decision makers. Who are the decision makers? Who is in power to choose curriculum?

In New York City recently when we sort of centralized the science curriculum and developed a new city-wide scope and sequence, principals were told that they could choose one of two approaches to elementary school science. They could either choose the Full Option Science System, the FOSS System, or they could choose a textbook system with additional hands-on activities suggested at the end of each chapter.

Who actually made the choice in many cases? The principal delegated a teacher who was free that day to go down to a fair and go eeny, meeny, miney, mo with a little slip that said this is how much money you have to spend. That is not how you choose curriculum.

If the city really felt that the inquiry-based approach was the most important one, they should have just funded it. They should have said this is what we are doing and if you want to do more, that is fine, but you must put Full Option Science System on your budget for this year or show how you are doing a full inquiry-based alternative science curriculum otherwise.

Mr. RUPPERSBERGER. Okay. You know, I think one of the issues there is it is just not only the school system. I think you have got to get academia, elected officials, the business community all involved. And that will really help move policy forward.

Dr. HILL. Yes.

NSA AND STEM EDUCATION

Mr. RUPPERSBERGER. I represent NSA. It is in my district. And we are trying to develop a STEM program, there are STEM programs within the State of Maryland, but a STEM program literally on the campus of NSA and focusing on maybe even late elementary or early middle school, looking at a regional type project that could really identify these children who have the aptitude. I think you have to have certain children who have aptitude in the area of math or science or whatever. And one of the things, one of the focuses is to have it as if it was an internship.

And the culture change of these kids who not only are in a classroom but then could also maybe, as long as you do not violate the classified issues, you have these children come to a campus and they grow. And they have also become really patriotic in the mission of what an NSA or what a NASA—I mean, we have Goddard right up the street on 295, but do this all over the country. And, you know, we can look at certain positive programs. I think there is a school in Virginia. I know there are a couple schools in Maryland, in Anne Arundel County, places like that that are successful, but it has got to grow nationally.

How would you recommend that we do that?

THE NATIONAL SECURITY PERSPECTIVE

Dr. HILL. Well, if I could say something from your original statement. I mean, I am glad that you are kind of coming from a national security perspective because we need to have that same kind of political will that we have around our national security in the field of education.

In the 1950s, when we perceived Russia as a threat and the launch of Sputnik as a threat, we put the resources into science education and it really paid off. And we need to have that same kind of resolve again because it is a national security issue.

When you have this large number of under and uneducated people, you know, particularly congregating in our inner cities, that is much more of a threat to our future security than foreign terrorists, for example. And if we had the same kind of political will to find the resources wherever—you know, when we went into Iraq, we found the resources. We need to do that same kind of thing, find the resources to transform these inner city school districts.

Mr. RUPPERSBERGER. I am glad you raised the issue of Sputnik because that was very dangerous to our country and the United States of America responded by putting a man on the moon within 12 years.

And, you know, if you look at where we were then and where we are now, it used to be that astronauts were just as popular as NFL quarterbacks and that is not the case. So it seems there needs to be, you know, a reinvigoration.

I think part of the policy is that—I think the country is just tired of us going back and forth to the space station. We need a goal that the country can get behind and bring excitement to these children. This is extremely important.

LOCAL SCHOOL DISTRICT ISSUES

But, you know, one thing I, and I know I am probably over my time, I want to raise this issue, one of the issues that you are going to find, and I know just when I am trying to work on the STEM Program in my jurisdiction is still, it is the politics of the different counties, the different school systems.

If you are going to have a positive STEM Program, you need a regional program, regional involving other counties, regional involving the cities, whatever, so you can identify it from a regional. And, yet, it seems that there is so much either litigation or policy that it is difficult to get children from one county to another county and that cooperation. So there has to be some really strong political will.

Are you seeing that as an issue also, the bureaucracy or standards within school systems and not wanting to cooperate or have a regional type program?

Dr. MIELE. I actually wanted to say a couple of things about that.

I actually was privileged in the 1960s to participate in an NSF-funded internship program at Columbia University. My junior high school science teacher said you are going to go do this and I do not care what you want to do on Saturday mornings because you have got talent in science.

So I went to the Columbia Science Honors Program. I later was a faculty member there for 16 years teaching students from the region, a 50-mile radius, but, again, that is one of those things where NSF type funding works because to transcend the regional political power, you have to have something that is outside school hours and funded separately.

THE INNOVATIVE ROLE OF JUNIOR FACULTY

There is another issue with the success of that kind of project and that is that junior faculty, the ones who are most likely to participate in innovative programs, such as bringing a high school student into their lab, are the ones who are the most at risk of not getting tenure. They need to focus on their research. Risking having a high school student in the lab means their research is going to go slower and perhaps maybe even suffer a little mishap because you do not have a graduate student. You have a kid taking attention away from your very important research.

So there has to be some way to protect junior faculty who are willing to invest in our young people and willing to mentor them. And right now that is not the case. I see again and again junior faculty who are willing to work with young people and to pay attention to science education and to work hard on their undergraduate classes to be the best teachers they can, to use innovative instruction. Those people do not necessarily get tenure because they are distracted. They are distracted.

I also want to point out that we need a scientifically literate general population in order to make the proper choices for our future. So we do need those people who are going to be scientists, but everybody has got to understand the value of science and evidence-based decisionmaking. Otherwise, we are going to be in big trouble.

Mr. RUPPERSBERGER. I do not disagree, but we have to really focus on STEM too.

I know I am over my time. Can I ask one more?

Mr. MOLLOHAN. Yes.

TEACHING INSTEAD OF RETIRING

Mr. RUPPERSBERGER. Okay. Another issue I think, and you raised the issue with me, is the instructors, the teachers. We have a baby boomer generation now that is a lot healthier, they are working longer, whatever, a lot of retired scientists, rocket scientists, engineers, whatever. And, yet, in order—and who probably can come back and help teach and teach hands on the way it is in the real world, not just from an academic point of view.

And, yet, because of the rules and regulations and because of teachers' unions and all the issues that we deal with, it sometimes is very difficult to get those individuals within a system or because the school system will say, well, you are not authorized, you know, you are not certified, you do not have your master's degree and this or whatever.

And it seems to me that if this system is going to work and we have those resources out there, we have to find a way to develop a STEM Program that will be the best it can be and we have to have some flexibility as we relate to our contracts with our teachers and whatever.

And I am not saying, you know, we do away with teachers' unions or anything of that nature. I am saying as it relates to STEM, you have to develop curriculum that is going to work. And it is just a shame that we have a lot of qualified people that can come back and help teach what we need to do in STEM and make it exciting because a lot of these individuals are former people who worked at NSA who worked on space programs and might have another ten years.

So if you have any idea on that, that is something we have to work on also.

Dr. MIELE. I will tell you I myself am not a New York State certified teacher. I have a Ph.D. in molecular biology.

Mr. RUPPERSBERGER. Did you hear that?

Dr. MIELE. I am not a certified teacher. If I wanted to teach——

Mr. SERRANO. Neither am I.

Dr. MIELE [continuing]. I would actually have to go back to school and get 18 credits in education even though I have taught those classes.

Mr. RUPPERSBERGER. Uh-huh.

Dr. MIELE. So I agree. But I must also say that I know full well that I was not prepared with my Ph.D. to walk into a high school classroom and teach. I was not. I needed to learn quite a bit about how young people learn. And I was——

Mr. RUPPERSBERGER. I agree.

Dr. MIELE [continuing]. Very, very fortunate to do that sort of in my own laboratory because as a faculty member in the Science Honors Program, I actually taught high school age students and I figured out for myself what worked and what did not. I was surprised to learn that it was completely congruent with the National Science Education Standards. When I read them, I went, oh, I could have written this. I figured it out by trial and error.

But, again, I think that we need these alternative pathways for current Ph.D. and master's holders. They do need to spend some time learning about——

Mr. RUPPERSBERGER. I agree with you. And you do need standards. You always need the education standards. And I am not saying it is a hundred percent. I am just saying there is a group out there, that we have to find a way. We find it in other areas. We have people who come back who are retired military and they are back working government, whatever. We need to focus on that, though.

And with the partnership between the teachers and the school administrators and these individuals, we should be able to help them train them and work as a team together.

Dr. MIELE. It is a priority.

Mr. RUPPERSBERGER. Thank you for your comments.

I am sorry. I have to go back to Intelligence and the no window—well, we do not have windows here either.

Mr. MOLLOHAN. And we are pretty intelligent here. We have got all these educators.

Mr. SERRANO. I agree with you. It is pretty intelligent.

Mr. MOLLOHAN. Yes.

Dr. HILL. And I hope you will continue that idea of regionalism because I think that has a big impact in most——

Mr. RUPPERSBERGER. And it gives you strength.

Dr. HILL. Yes.

Mr. RUPPERSBERGER. I mean, it is the only way to go, no question.

Dr. HILL. And you get away from, you know, it is okay for those kids over there not to have, you know, as long as my kids are okay, you know, that is the mentality.

SKILLS TRAINING VERSUS INQUIRY

Mr. MOLLOHAN. Let me go back to this and let both of you talk a little more about skills training versus inquiry. And you used that word skills when you were talking about reading and saying that, you know, that inquiry is great and wonderful, but kids need to be able to read when they get to, and need to have skills to read.

And, Dr. Hill, you also alluded to that and I am not sure where I wrote it down. But just talk to us about the—Dr. Miele, you begin and then Dr. Hill. You need skills and inquiry is in your judgment essential if we are really going to develop the potential and have the result that we—in terms of numbers and quality of youngsters coming into math and science and just the general population being literate in that. So if you would talk about the balance that exists there and how to achieve it.

Dr. MIELE. I think that in the 1970s, there was a tendency to throw the baby out with the bath water. And in the interest of developing inquiry skills, there was less focus on content. It is not a true dichotomy. The best way to learn science is to learn the content that the scientific community agrees is foundational to progress as a practitioner and the processes that those scientists use.

INQUIRY SKILLS

So what are the skills? What is inquiry? Inquiry means applying the basic science skills. The first skill is observation, looking at the world objectively, knowing the difference between what everyone would agree is happening and what you think about it. I may see a flower opening up and think, ah, how beautiful. But as a scientist, what I have to look at is, well, how did the petals separate and what is the position of the pistils and the stamens. Does the pollen mature at the same rate as the ovary? And I need to know these terms in order to discuss it with someone else who is a botanist.

So there is language and vocabulary that is unique to every scientific discipline. As a biologist, I do not speak physics. I am not at all versed in geology. I am learning because I try to talk to my colleagues and develop that common vocabulary. But one of the first things you learn when you are a specialist in one area and you talked with specialists in another area is that you use the same words and you mean different things.

So in order for a student to become truly proficient to enter a STEM profession, by the time they are finished with high school, they have to know how to look at things objectively. They have to know how to measure things and what kind of measurement is appropriate to the task. They have to know how to collect and organize data. They have to know how to analyze that data and what the appropriate tools are to analyze any given kind of data. Is it qualitative? Is it quantitative? Is it some combination of the two?

They have to understand the language of their discipline and be able to speak it. Well, that takes a long time. And how are we going to do it? We are going to do it by starting with kindergartners, maybe even pre-K. In pre-K, we develop basic language. What do you call something? How do you describe it? What does it do? That is, you know, it is nouns, it is adverbs, it is adjectives, it is verbs.

Mr. MOLLOHAN. So that is skill training?

Dr. MIELE. This is skill training.

Mr. MOLLOHAN. Okay.

Dr. MIELE. As a scientist, you are learning. As a scientist who is five and looking at a cloud, it is a very different person than a NASA or NOAA meteorologist looking at a cloud or an astronaut who might be looking from different perspectives.

That five-year-old is thinking that fluffy white thing looks like milk or cotton candy. Well, do you think it might be cotton? Well, if I am thinking magically, yes. But if I am thinking about somebody who threw cotton up in the air and it always came down, then, no.

So how do you decide which kind of thinking you are going to use when you look at something? How do you develop the basic skills of common sense looking at patterns of nature that a scientist uses as opposed to the skills that you would be using as a poet or an artist?

You need to practice and sometimes you practice looking at things as an artist and sometimes as a poet, sometimes as an objective writer and sometimes as an analyst. When you are looking at nature as an analyst, you are applying science process skills.

Mr. MOLLOHAN. How do you teach it?

Dr. MIELE. One step at a time. You start with observation. You start with recording what you observe, learning to develop language. Just describe this rock, describe it well enough so that your rock can be separated from everybody else in the class's rock. Even a group of apples. Can you describe your apple so well that when we pile it back up on the table with all the apples we picked——

Mr. MOLLOHAN. Yes.

Dr. MIELE [continuing]. In our class, you get the right one? And maybe that means I have to not only be very detailed, but maybe

I have to start doing things like measuring and I have to measure accurately. Accuracy becomes important.

Mr. MOLLOHAN. So your——

Dr. MIELE. So one step at a time.

Mr. MOLLOHAN. That is an integration of skills learning within inquiry learning?

Dr. MIELE. Absolutely. So you do these things and you are integrating mathematics at every step of the way.

Mr. MOLLOHAN. Let me ask you, Doctor. I now remember how I would like to introduce you to this question. Robert P. Moses has written Radical Equations: Civil Rights for Mississippi to the Algebra Project. And I understand that this is a project that is also in Petersburg.

Dr. HILL. Yes.

Mr. MOLLOHAN. Is that correct?

Dr. HILL. Yes.

Mr. MOLLOHAN. Well, that would suggest that learning the skill of algebra is fundamental to creating this infrastructure, if you will, intellectual infrastructure for moving to inquiry-based learning.

I am just curious. How do you teach——

Dr. HILL. And both. I mean——

Mr. MOLLOHAN [continuing]. The fundamentals of algebra and——

BUILDING A COGNITIVE NETWORK

Dr. HILL. But one thing that the inquiry-based learning does is building these cognitive skills. You know, it is like building this network of associations. And that is basically how you learn. You make new associations and you put them into your network of previously existing associations and your network expands. So every time you learn a new fact, your network has to accommodate that fact.

And so if you have an impoverished network, it is difficult for new facts coming at you to stick. And just getting new facts does not do anything for your network. You have to engage with the material in some kind of way. You have to use this inquiry-based processing or you are using different modalities that make these associations that then lead you to be able to hold on to the facts.

And so if you just have a fact-based approach, and we see this with kids all the time, they get these facts thrown at them, they are isolated, they do not see any connection between them. If they learn them at all, they are just memorizing them in separate kinds of ways. And they do not retain it. You know, they might take a class, have a hundred different facts, and one year later, they have forgotten all of them because they never were integrated into this underlying cognitive structure.

So the approach that the algebra project takes and the things that we are doing with this cognitive training are trying to develop the structure and then connect the information to the structure and to the processing that is going on, too, because both of those things are important.

And, yes, the algebra project in particular is very good at taking abstract concepts from mathematics and connecting them to the everyday experience of the kids so that they are making these associations, they are making these connections. And these are not just isolated facts or facts that are so abstract they have no connection with them at all.

STUDENT MATH ACHIEVEMENT EVALUATION

Mr. MOLLOHAN. Is student math achievement being evaluated and do you see any problems with the evaluation instruments in general use today? You spoke to that a little bit. If you would——

Dr. HILL. Yes. I mean, we are basically, because in order to get cooperation from the school districts, we have to tell them this is going to impact your standardized test performance because that is all they are concerned about. And so we are using those actual standardized tests to see what kind of change we get in the performance of these kids after a year. But it is a flawed instrument and there are some instruments out there that would be better at capturing that process that is going on as you are using inquiry-based education and developing these cognitive skills.

TESTING INQUIRY SKILLS

Mr. MOLLOHAN. And that is what you, Dr. Miele, were speaking about when you said that the testing needs to be testing that captures the inquiry-based learning skills?

Dr. MIELE. Exactly. The testing needs to see if the students have the skills, not just the content knowledge, not just facts that they recognize, which is the lowest level.

In the scientific community and science education community, we refer to getting knowledge like this as constructivism. You are basically building a house, building a structure of knowledge that includes facts, but the facts are the lowest level. It is the theories that you want to get to and it is the processes that allow you to build those theories.

Mr. MOLLOHAN. How do you test inquiry learning?

Dr. MIELE. Well, one of the things that you can do, I actually wanted to talk a little bit about one test that I rather like, the New York State Earth Science Regents examination that many people feel is sort of a flawed instrument because it does not test enough memorization. I think that is ironic because we are so used to memorization being the paradigm that when it is not the paradigm, we reject it.

This New York State exam requires students to read a question, recognize what the question is asking, which means that they have to have the vocabulary to know what the question is about. Then they have to go to the back of the exam where there are reference tables, find the appropriate reference table, find the appropriate data from the reference table, perhaps do a minor algebraic manipulation of it to find the right answer, and then answer a multiple choice test.

You have the efficacy, the very quick and easy method of evaluation of scanning a multiple choice test, but it is a multi-step process. So it is actually looking at what the student can do, not just what the student can recognize.

So it is actually possible to make a standardized test, a simple kind of familiar standardized test that can break out these things.

You can also have a test that asks the student to look at something and say, well, what does that measure, what is the appropriate measurement there. So it is a proxy for a hands-on measurement assessment.

There are a number of ways that you can create situations in a test which will look at process. Can you group things appropriately? Can you look at a chart or a table and collect the right data from it to get the correct answer?

Dr. HILL. Yes. And even with a standardized test, depending on how the questions are framed, you can even get higher level thought process involved in a multiple choice test if it is not just simply recognition memory. You know, you are just recognizing the right answer. But if you have to do some kind of processing to distinguish between the alternatives——

Dr. MIELE. So I think what we need is developmental and cognitive scientists helping us in test design. Traditionally, these tests are designed by practitioners of K to 12 education coming together as a group and deciding by consensus what a good question is, but we need this higher level of awareness so that we can make sure that we are looking at a higher order of thinking in these exams.

TEST SCORES AND SCIENCE INTEREST

Mr. MOLLOHAN. Dr. Hill, are you finding a correlation between student scores on State standardized tests and their students' interest in achievement in science?

Dr. HILL. No, not at the moment, and mainly because those State tests are just minimum standards. They are not really geared toward assessing the person's creativity or their inquiry skills or any of that. So it is almost like minimum literacy in these various areas. So, they are not good predictors of who would go on to a career in STEM or in any other area that I know of.

Dr. MIELE. We have found similar findings with our Brooklyn outreach for science and careers. We basically do not have enough science majors at Brooklyn College. They all want to be economics majors, education majors, or pre-med because they want to make money.

Our students are by and large first generation students to go to college and their going to college is their ticket to American success. But they do not know that you can be successful as a scientist, so that is a major problem. We have a disconnect between what students think you need to do to be financially successful and the various paths to success.

We have been able to break that by exposing students to career opportunities, but again, that is a band-aid approach for our particular little pocket of students. We really need some kind of broader systemic way of making clear to students that science is something that is fun to do that you can be somewhat autonomous, independent. You can do something different every day. You can make a contribution and you can feed your family and buy a house.

ARE IMPROVEMENTS READY FOR BROAD IMPLEMENTATION?

Mr. MOLLOHAN. Are the improvements that you described ready to be spread to more schools and school systems, and we spoke of this a little bit, but let me give you an opportunity to answer specifically, and what do we need to do so? Dr. Hill?

Dr. HILL. Yes. There are certainly a lot of evidence-based practices out there that are ready to go. It would take political will. It would take an independent principal or some other administrator who is willing to implement these things and not worry about the immediate consequences to their SOL test performance or whatever the standards they are using.

So, yes, they are ready to go. We just need to create a climate in which that could be implemented on a widespread basis.

Mr. MOLLOHAN. Can you cite specific examples of models where this turnaround has occurred based upon inquiry-based learning?

Dr. HILL. Well, Petersburg is a good example. As I mentioned, over the last three years, we have seen their test scores go up. We have seen the engagement of the students go up. You know, we are in the middle of a three-year project. We will have a lot more data in a year-and-a-half from now. But all the trends are in the right direction, and we are excited about the possibilities. And a place like Petersburg is small enough to be kind of like a little laboratory.

Mr. MOLLOHAN. Are you working in the middle schools?

Dr. HILL. Primarily the middle schools and the high schools, yes.

Mr. MOLLOHAN. And what has been the story with regard to scores——

Dr. HILL. Well——

Mr. MOLLOHAN [continuing]. In middle schools?

Dr. HILL [continuing]. I think I shared with you——

Mr. MOLLOHAN. Well, share it with me again.

Dr. HILL [continuing]. Some of that data. The middle school that we are working with in 2007 had an average SOL score of 39.7 and the passing score is 70. And this year, their average SOL score in math was 88.86. So there has been more than a twofold increase in three years in their math scores in that middle school and similarly in the high school.

And, again, we have had kind of a three-pronged approach. We have had the approach of cognitive education. We have had an approach of the algebra project, pedagogy, and community organization and involvement. And I think it takes that kind of multifaceted approach to really make a difference.

Mr. MOLLOHAN. Are other schools in Virginia coming down and seeing what you are doing and saying we would like to replicate this?

Dr. HILL. Not yet. We are trying to get the word out and hopefully we will. I mean, my appearance here was the result of an appearance on NPR, so maybe the word is starting to spread.

Mr. MOLLOHAN. Are you working with any kind of innovative programs or organizations like the Darden School at University of Virginia or any of those?

Dr. HILL. No. Right now we are only working with two outside organizations other than Virginia State University and that is the Algebra Project, Incorporated and Learning RX which is the cognitive training organization.

TEACHER-STUDENT RAPPORT

Dr. MIELE. You know, I want to just mention something else. One of the problems that we have with middle school and high school is it is the opposite of the problem we have with the elementary school system. There you had specialists. The people who identified themselves as scientists or mathematicians fairly early on chose higher education in that area and as a result are not always aware of the struggles of the average student when confronting these subjects.

So we very often have a disconnect between the math teacher or the science teacher and their students because the math teacher says, well, you know, math is cool, it is great, and they have not figured out how to convince their students that that is true.

We have the same problem with our science teachers. And, again, because our science teachers traditionally go through a more formal kind of education in higher ed, they have not had any inquiry instruction in their college experiences, they are not really prepared to teach inquiry and they are not committed to it as an approach to instruction.

So we really need that change at the middle school and high school level as well. Middle school gives us some opportunity because we have, many teachers who are moving up from elementary school who are elementary school science specialists who really got so excited by it that they wanted to teach it at a higher level. And they have been able to bring a great sort of elementary school approach to middle school, but with more content understanding.

Dr. HILL. Yes

IMPROVING HIGHER ED

Dr. MIELE. I think that we need to get our college teachers also encouraging our undergraduates to think about how the discipline evolved and how we know what we know and what you need to do to get to the next step because myself as a graduate student, it was only my last year at college that I was introduced to how we know what we know. And that was just a short step. Then I had to start figuring out new knowledge myself the next year as a graduate student.

So we need some changes in higher ed as well and that, I think, will allow more people to stay in STEM who think that they might. We are losing way too many potential science and math majors in their freshman year.

Dr. HILL. We are working with our math ed people at Virginia State in particular to try to put some of this innovative pedagogy into their content for teaching math teachers. So that is an issue.

And I have also found even at the middle and high school level that often the math and science teachers, let me think of the charitable way to say this, they are not able to do much more than process facts either. I mean, they are not very inquiry based in their background.

Mr. MOLLOHAN. Did not learn the approach?

Dr. HILL. They did not learn it that way.

Dr. MIELE. They did not learn it that way.

Dr. HILL. Yes.

Dr. MIELE. They are good memorizers.

Dr. HILL. Yes. Particularly in math, I mean, they can plug in a formula, but they are not able to conceptualize the connections and what this formula is actually saying in terms of the real world.

Mr. MOLLOHAN. Can teachers be retaught? Can they be reoriented? Can they be retrained?

Dr. HILL. Yes. And that is what we are doing with this algebra project approach. We are mainly focusing on the teachers and their pedagogical skills.

Dr. MIELE. Sixty hours of professional development that actually is inquiry based, actually is active learning.

Mr. MOLLOHAN. I am sorry. Say that again.

Dr. MIELE. Sixty hours seems to be the minimum for transformation.

Mr. MOLLOHAN. You said that before. To re-educate and to educate?

Dr. MIELE. Yes.

Mr. MOLLOHAN. We are coming to a close. I would like to give you all an opportunity for any final thoughts that you would like to put on the record for the Committee.

Dr. Miele, why don't you go first?

Dr. MIELE. I think I would like to take this opportunity to speak again about the issue of the support for college faculty to make sure that these transformations can happen.

In order for us to have the most robust STEM practitioners at the highest level, we need the best instruction at the college level and we need to make sure that junior faculty who embrace inquiry do not get pushed out by senior faculty who are threatened by it or do not see its value.

I do not know what you can do to protect them, but it is an important issue.

EDUCATION REQUIREMENTS IN SCIENCE GRANTS

Mr. MOLLOHAN. Well, why don't you help us? We fund NOAA and NASA, NSF. We do not fund the Department of Education. But in those accounts, how do you think that we could help——

Dr. MIELE. Traditionally——

Mr. MOLLOHAN [continuing]. Within that area?

Dr. MIELE [continuing]. As I understand the—I have been out of the pure science grants area for 20 years myself having recreated myself as a science educator, but pure science grants have a small requirement that there be an educational component.

If that could somehow be made a little bit more robust, a higher amount of the score for the grant actually count for meaningful inclusion of inquiry learning or the quality of their instruction in their undergraduate class work, how will this research transform their undergraduate class work, that way, it would be a science grant, so it would count for promotion and tenure, but it would actually have some meaningful impact on undergraduate instruction.

Mr. MOLLOHAN. Well, we will ask our NSF friends when they come to testify about that.

Doctor.

Dr. HILL. I would piggyback on what Dr. Miele just said. The grants process, as I mentioned earlier, is kind of stacked against young faculty members, particularly at teaching institutions. If there are some ways that NSF could come up with some more creative— I mean, they do a lot. I do not want to complain about NSF because they have a tremendous amount of science education funded programs.

But if we could just add another more innovative funding mechanism of, say, a research initiation grant that could be given to a new faculty member. I mean, the way it is now the grants are, the proposals are evaluated by, you know, peers in the field and so they are looking at credentials, they are looking at publication record, they are looking at what else they have done.

And so if we want to get to where particularly the minority kids are, which are HBCUs, we need to have some more open kinds of innovative funding mechanisms that allow these faculty members to develop their program of research. And by necessity, the people they would be working with would be minority STEM majors.

So I guess this would be under the term of research initiation grants. If there could be more research initiation grant funding at places like NSF, it would be very helpful in this area.

Mr. MOLLOHAN. Could be more research initiation grants?

Dr. HILL. Yes, to allow the researchers where——

Dr. MIELE. Research one institutions.

Dr. HILL. Exactly. Since I guess—and not just HBCUs but Brooklyn College and—

Dr. MIELE. Yes. Places that are research one are going to have a higher opportunity to get funding for their junior faculty to do pure research. Those of us who are at institutions where research is not the high priority, but education is, our junior faculty are at something of a disadvantage.

Mr. MOLLOHAN. In the NSF grant process?

Dr. MIELE. The NSF grant process, yes.

Dr. HILL. NIH, you know, all the funding mechanisms.

Mr. MOLLOHAN. And so what good do we achieve if we address that problem at the——

Dr. HILL. Well, for one thing, you are kind of bringing together research and education because these are the places where the education is going on, where the teacher education is going on.

Mr. MOLLOHAN. But they are not the places that generally have favorable responses from NSF for grant——

Dr. HILL. Yes.

Mr. MOLLOHAN [continuing]. In response to grant——

Dr. HILL. Exactly.

Mr. MOLLOHAN [continuing]. Solicitation?

Dr. HILL. Yes.

Mr. MOLLOHAN. And so to fix that, it should be fashioned to bias——

Dr. HILL. And, again, NSF does a good job.

Mr. MOLLOHAN. No, no, no. We are not bashing NSF.

Dr. HILL. Yes. Another track would be good.

Dr. MIELE. Integrates research and instruction——

Dr. HILL. Yes.

Dr. MIELE [continuing]. That would be targeted for nonresearch institutions. So the goal is to bring young people into the research paradigm.

Dr. HILL. Because NSF has some programmatic kinds of grants for things, places like HBCUs. They do not have the research dollars targeted for kind of start-up type research careers. And that is the kind of thing that we need.

Mr. MOLLOHAN. Okay. I am going to ask you all for the record, this is my 28th year and I think 20 probably—anyway, long enough on this Committee and I believe every hearing that I have sat with NSF, this question of youngsters in America falling behind by all kinds of measurements, youngsters around the world with regard to math and science education has always been a part of the presentation.

And, okay, well, what are we going to do about that or are we just being scared so we will fund more for NSF? What is going on here? After 25 years, there ought to be some really concrete approaches to dealing with the issue, number one. And then there ought to be some desired results coming out of it, number two.

And during that period, not being an expert in the area, but the concrete proposals and the desired results have eluded us, I think. And so I think it is fair to take the kind of testimony you are giving us and ask NSF, look, let us get down to brass tacks here. How do we actually achieve those desired results?

And so I would like to ask you to in writing, if you would, and you have been so forthcoming here to begin with in your testimony and your attendance, but to address that question.

We fund NSF. We do not fund the Department of Education. But NSF obviously plays an important role here, particularly at the research level. So how do we work with NSF through the appropriations process to help facilitate the desired results that everybody wants as an outcome?

[CLERK'S NOTE.—The written material follows:]

Follow-up Comments

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I would have three suggestions on how funding could be directed to produce a greater impact on the actual performance of students in STEM classes:

1. There have been a number of researched-based best practices that have been identified in the research literature for the past few decades (such as cognitive training in my own research), yet many of these practices have not been widely implemented. There are many factors contributing to this, such as bureaucratic inertia, pressure to cover existing curricular topics, pressure to prepare for standardized tests, and general resistance to change. To overcome this, the committee could directly fund demonstration projects in school districts willing to institute the new pedagogy/content district wide. To qualify for the funds, the school district would have to demonstrate complete buy-in at all levels: school board, administration, and teachers. Such a large demonstration project in a "real-world" setting could have a great impact on a wider dissemination of these methods.

2. Provide funds through agencies such as NSF for research at non-research 1 institutions, such as HBCU's and teacher colleges. Funding in the form of research initiation grants could help faculty members who are burdened with heavy teaching loads to develop programs of research in the area of STEM education. The advantage is that these kinds of institutions are the ones that produce the science and math-ed graduates who will become the next generation of teachers. HBCU's produce disproportionally higher numbers of minority graduates in STEM fields, and research by faculty members at these institutions would be better situated to study barriers to minorities in pursuing STEM careers.

3. There needs to be a recognition that the problems of STEM education in this country goes beyond the STEM classroom. More research is needed on the impact of language arts on STEM performance. There also needs to be a recognition that the problem goes beyond the schools. Students in many inner city and rural school districts experience a high number of family and community issues that impact their performance in school. Community organizing is often needed around low-performing schools to provide needed non-academic services which can improve student performance in schools. One of the ways this is happening is through "K-16" partnerships between school districts and local colleges and universities. Funding mechanisms should be in place to support these efforts, particularly with two-year institutions.

Thank you for this opportunity to make additional comments.

Recommendations to better get inquiry-based instruction supported through NSF funding:

Provide funding to improve state science testing so it will be informed by cognitive science, and higher order thinking skills gained through inquiry learning are properly valued and evaluated.

Continue to provide incentives for development and implementation of inquiry-based courses at undergraduate institutions from community college to research 1 institutions.

The 1999 NAP publication of Bransford et al.'s *How People Learn: Brain, Mind, Experience and School* and Donovan et al.'s *How People Learn: Bridging Research and Practice,* widened the dialogue on the science of learning to reach college faculty. Nonetheless, most college science faculty remain unaware of the contribution that cognitive science has made to developing instructional approaches that work. Many, if not most, still question the new focus on assessment. The evaluation of faculty performance based on what students have learned rather than what was taught remains a foreign concept in many biology, chemistry, geology and physics departments. There is an aphorism in education circles that states that teachers teach as they have been taught. Science faculty members who have the been taught using inquiry-based instructional techniques including Problem-based Learning, are more open to using these techniques, but may be daunted by the reaction of more senior faculty who will ultimately vote on their tenure. I suggest several practical measures that may help.

- We need not reinvent the wheel. To induct more junior faculty into using inquiry-based instruction, use what works. Provide incentives for recipients of R&RA grants to attend Project Kaleidoscope (PKAL) meetings, On the Cutting Edge Geoscience Faculty Development Workshops (open to all disciplines,) meetings of the National Science Teachers Association (NSTA), NSF Chatauqua short courses, AAAS and other proven faculty development institutes. This will provide mentors, networking and practical ideas and resources for using inquiry-based instruction in their own classrooms. The faculty should be compensated for their time as well as their travel if these occur outside contractual teaching times.
- American Physics Association (APA), and American Chemical Society (ACS) also offer workshops on curriculum as well as research. Provide incentives to attend these workshops.
- Consider an RFP for an On the Cutting Edge type faculty development project in other disciplines.
- Some R&RA funding can be reserved to support up to an extra 3 months of faculty salary for development and teaching of college freshman and sophomore science and engineering courses, particularly for STEM majors, that use inquiry in a significant way to those willing to participate in the above mentioned faculty development OR who have already done so.
- Provide incentives (higher grant limits?) for recipients of EHR institutional grants who demonstrate that inquiry-based teaching and higher order assessment are valued in the tenure and promotion process of research faculty in the natural sciences.
- Physical constraints limit the participation in inquiry learning on many campuses with willing faculty. Encourage applicants to consider requesting hard costs to upgrade classrooms or laboratories to support inquiry learning as part of research grants. Allow such costs for EHR grants.

Respectfully submitted:

Eleanor Miele, Ph.D.

Dr. MIELE. One of the things that I discovered in working with the Museum of Natural History and the zoo is that there is no NSF funding for formal partnerships with informal science institutions.

In other words, for a school district to say during school hours we want these informal institutions to help us with our State mandated core curriculum instruction, it is only for after school and enrichment. Well, here is this wonderful resource that can expose young people to career opportunities in the sciences and, you know, all of our major cities have them and many of our college campuses have institutions associated with them that can fill this role. Even the Boy Scouts, the Girl Scouts, Explorer Scouts, institutions like that that have a strong natural knowledge mandate——

Mr. MOLLOHAN. Well——

Dr. MIELE [continuing]. Can help with this.

Mr. MOLLOHAN [continuing]. Maybe the people who——

Dr. MIELE. That is a new area that is not funded right now.

Mr. MOLLOHAN. Yes. Maybe the peers that review, and I am not interrupting, I want you to hold your thought and I have trouble holding mine, so let me say it, maybe the peers who review these applications do not appreciate that the importance of those partnerships and——

Dr. MIELE. It is actually in the guidelines that you cannot do it for a formal partnership. It is only for enrichment and outside school hours. So——

Mr. MOLLOHAN. Okay. I do not know exactly what that means, but I am going to ask you to put that in your written——

Dr. MIELE. Okay. And one thing I wanted to mention is that when we judge ourselves against the international standards, remember that places like China and Russia do not give their young children who have talent in math and science the choice of what to do with their lives. They are funneled into math, science intensive instruction from the time they are 12 years old. They are begun on college level course work much earlier than our students and part of that is because they are not given the chance to, you know, to be Shakespeare.

So they get what they are putting in. They are creating scientists and mathematicians for its political and social construction. And it makes sense for a building economy to force their students perhaps into——

Mr. MOLLOHAN. They are pushing and we are trying to pull.

Dr. MIELE. Exactly. Exactly. We are trying to, you know, cajole, coax, and we are not doing it very effectively.

As I say, I myself left a career in science because it was not supported, frankly. It was a difficult, very difficult life writing grants, hoping you will get them, exposing yourself to all kinds of dangers for the benefit of mankind and not—frankly, I did not make enough money as a young scientist to pay for my kids' childcare and my extra travel.

Mr. MOLLOHAN. It is a dangerous world out there no matter what profession you are in.

Dr. Hill, final thoughts? You do not have to.

Dr. HILL. Yes. I mean, I think most of the things have been said already. Anything you all can do that will bring more funding in this area, I think, is great.

And I think again if you look at our political will as a nation, we have not had science as a priority and our funding has reflected that. And so anything you can do that would kind of get the word out that we need to make this a priority, I think it is important.

Mr. MOLLOHAN. Well, funding is going to be scarce which makes your thoughts about this more important so we can focus scarce resources. And we so very much appreciate your appearance here today. I thought it was an outstanding hearing, and we look forward to your written statements and any other thoughts that you have.

I know you are working closely with our excellent staff which we appreciate your having done in preparation for this hearing. I notice with your eyebrows, you recognized I am right about——

Dr. HILL. Yes.

Mr. MOLLOHAN. Thank you for your testimony here this morning.

Dr. HILL. Thank you.

Dr. MIELE. Thank you.

THURSDAY, FEBRUARY 4, 2010.

SCIENCE, TECHNOLOGY, ENGINEERING AND MATH EDUCATION

WITNESSES

DR. JULIE LUFT, ARIZONA STATE UNIVERSITY

DR. CRAIG STRANG, UNIVERSITY OF CALIFORNIA, BERKELEY

Mr. MOLLOHAN. The hearing will come to order. Thank you all for being here today. And we are starting a few minutes late.

We ordinarily would not start without the Minority representative, but Mr. Wolf is running a little late, and it is fine with him if we start. So we are going to start.

Welcome. Good morning to the second hearing of the Commerce, Justice, Science Subcommittee on Science, Technology, Engineering, and Mathematics, STEM, Education.

In testimony yesterday, we heard about two examples of STEM education activities and today we will hear two more. We also learned that development precursors do not always resemble the skill to which they are leading and how the environment around schools can be effectively used in inquiry-based education.

Did you not catch that? Yesterday we learned that development precursors do not always resemble the skill to which they are leading and how the—to which they are leading and then we also learned how the environment around schools can be effectively used in inquiry-based education. I will let you think about that.

Testimony helped us become aware of the challenges to transforming science education and including student activities such as devising original experiments, observing the natural world, using math and reasoning with data.

Today we will hear from witnesses recommended to us by NSF and NOAA as outstanding recipients of federal education funding provided through our appropriations. These witnesses are Mr. Craig Strang from the Lawrence Hall of Science at the University of California, Berkeley, and Dr. Julie Luft of Arizona State University.

Mr. Strang has pioneered the development of materials that help enable inquiry in STEM education. Dr. Luft has been both a middle and high school teacher and an educator of secondary school science teachers. Dr. Luft is currently the Director of Research for the National Science Teachers Association.

And thank you both for coming, being here today. Your written statements will be made a part of the record and then we would invite you to present your oral testimony and then we will follow with questions.

Dr. Luft, why don't you begin?

Dr. LUFT. Chairman Mollohan, thank you today for inviting me here. I am honored to be here to talk about inquiry-based science teacher education.

As you know and as you stated, I have been involved in science education for a long time. I was a former middle school and high school teacher and currently I am an academic in an institution of higher ed. Specifically I am a professor at Arizona State University.

In addition to my duties at NSTA, I am also an associate editor for the Journal of Research and Science Teaching and I am also an incoming fellow for the American Association for the Advancement of Science.

As you know, the National Science Education Standards have led the way in our thinking about science as inquiry. This document has made it explicit that science as inquiry is a content standard. That is something that all students should know about, have the abilities to do, and that they should understand.

And in the standard, it describes specifically what science as inquiry is. It includes among several things being able to ask questions, collecting data, analyzing that data, and sharing those findings.

In science teacher education, we think a lot about this standard and we think of it in two ways. We think of it as a way to teach and a way to learn. And our work in this area focuses on helping teachers to learn how to teach using this method as well as understanding how students learn in an inquiry setting.

Now, I know this sounds very simple, but it is really quite complex. And this is where most of my work has been. I have pondered how we can better assist teachers in implementing science as inquiry. My current work, which is funded by the National Science Foundation, is targeting a unique group of science teachers and that is teachers in their very first years.

So this is what we know. We prepare teachers to teach inquiry and we provide wonderful professional development for them to support their learning of inquiry. But when they first graduate, when they first come out of their teacher preparation program, they have no rich support to do inquiry.

So my premise was what if we intervened in that period and actually gave them very rich support what would happen. And NSF funded me to find out.

I followed 120 teachers over three years, the first three years, and we found out that with rich support to teach science, these teachers actually enacted more inquiry. And what we are finding out now as we go into the fifth year of this study, it is being sustained.

So this research is really important in that it gives new insight into how teachers can develop their practices and how we can strengthen them and how we can sustain them.

From this research, we found in addition to that conclusion that science induction, and that is what we call it, support is critical.

We have also found that teachers have great advances in how they understand how students learn in these first few years. In teacher preparation, we focus on that. But when they actually hit this classroom, their understanding of how students process science takes incredible leaps and bounds.

So this work has been critical. It has allowed me to work with several federal agencies. And I am hoping to continue this work. And in thinking about that, I was thinking about some key suggestions I might have for federal agencies.

First off, I think it is really important that this work, as work of a lot of my colleagues, that we think about how do we translate this or support this work so it can go into practice. We know this now. We found this understanding, but how do we actually put it in the hands of people who can use it.

I think there is also the potential for funding agencies to think about long-term support. We are beginning to understand more about how teachers develop their practice and how students learn, and these are going to be projects that require a lot of financial support to really get at some very important understandings.

And, finally, I think it is really important that we just continue our support for research in science education.

So I want to thank you very much for having me here today. I hope we can continue to talk about some of these issues, and I am looking forward to answering any questions you may have.

[The information follows:]

Testimony
Julie A. Luft, Ph.D.
Professor, Science Education
Director of Research, National Science Teachers Association
Mary Lou Fulton Institute and Graduate School of Education
Arizona State University

Before the
Commerce, Justice, and Science Subcommittee
U.S. House of Representatives
February 4, 2010

Chairman Mollohan, Ranking Member Wolf, and distinguished members of the Subcommittee, my name is Julie Luft and I am honored to be here today to discuss inquiry based science teacher education. I have been involved in science education as a middle and high school classroom teacher and as an academic in institutions of higher education. My teaching and research responsibilities over the years have focused on secondary science teacher education. Currently, I am the Director of Research for the National Science Teachers Association (NSTA), an Associate Editor for the *Journal of Research in Science Teaching*, and an incoming American Association for the Advancement of Science Fellow.

Thank you for inviting me to speak to you on the critical topic of science education. My passion for this topic was certainly inspired by my middle and high school science teachers, who heard my questions and encouraged me to find the answers. The investigations I engaged in were not always planned, nor were they in the textbooks. Instead, they provided me with an unusual opportunity to conduct experiments, collect and analyze data, and make conclusions. These early experiences were captivating in that they allowed me to explore what I did not know, develop solutions to problems, and better understand our natural and made-made world. As a teacher, I tried to provide these same opportunities for science as inquiry to my students.

The *National Science Education Standards* [NSES] (National Research Council [NRC], 1996) is explicit in its statement that science as inquiry is a content standard for K-12 students. This means that students need to develop the understandings and the abilities to conduct science as inquiry. This standard includes: "making observations; posing questions; examining books and other sources of information; planning investigations; reviewing what is already known in light of evidence; using tools to gather, analyse and interpret data; proposing answers, explanations and predictions; and communicating the results (p. 23; NRC 1996)." Ultimately, a science as inquiry instructional approach cultivates the abilities of students to think scientifically, which will help students better negotiate the different disciplines of science and help build their capacity to be scientifically literate citizens.

Science as inquiry is typically characterized in two ways: a way to teach, or a way for students to learn. Science teacher educators consider both approaches when working with future teachers. We have to provide programs with experiences in which teachers can learn about inquiry, so that they can create inquiry environments that provide an opportunity for their students to learn important science concepts. While this sounds simple, it is not.

In order to learn to teach using inquiry, teachers need ample opportunities to practice methods of inquiry instruction, knowledge in the content area they are teaching, knowledge about the nature of science, knowledge of how students learn, and access to inquiry based curriculum. Developing science teacher education programs that address each of these areas is possible, but it requires collaboration between education and science faculty, and teachers and administrators in local schools. In this collaborative effort, there also has to be time dedicated to the development and assessment of common goals and outcomes related to science as inquiry.

As a science teacher educator, I am always looking for new ways to cultivate an understanding of inquiry among our future and current science teachers. In developing courses and programs, I have to consider the challenges previously mentioned. To understand if my innovations, instruction, or programs are assisting teachers in developing their abilities around inquiry, I conduct studies and look at the findings of my colleagues.

Recently, I have been involved in research that examines how beginning science teachers create an environment of science as inquiry in their classrooms. It is important to study beginning science teachers because they know about inquiry, want to use inquiry in their classrooms, and will become experienced educators who use inquiry.

The National Science Foundation has funded this research project since 2004. In this study, my colleague and I (Dr. Gillian Roehrig, University of Minnesota) were interested to see if we could support beginning science teachers to use more inquiry than is usually observed in classrooms. To do this, we designed a study that following beginning science teachers during their first through third years in the classroom. While these teachers were in the classroom, they engaged in different professional development programs. Programs for new teachers are called induction programs. Half of the teachers participated in induction programs that focused on teaching science and science as inquiry, while the other half participated in induction programs that focused on teaching. In interviewing over 100 teachers every month and observing the teachers every other month for three years, we found that:

> **Teachers in science induction programs enacted more inquiry than did their peers in other programs** - The new teachers who had access to ongoing support to teach science as inquiry did create more inquiry environments. This support provided the new science teachers with assistance to create lessons, feedback on one's teaching, instructional materials, and countless opportunities to talk about teaching science.
>
> **Science teachers learn about student learning as they work with students** – As our teachers worked with students, they began to understand how students learned during inquiry instruction. This provided the new teachers with opportunities to understand how different instructional formats impacted student learning.

These findings are important for two reasons. First, they suggest that new science teachers need subject specific support as they begin to learn to teach science. Most induction programs for new science teachers focus on teaching in general, and not on teaching science. Second, faculty who prepare science teachers need to continue working with their teachers as they begin their first years of teaching. By focusing on teaching science and involving teacher preparation faculty in induction programs, new science teachers will be better able to develop an inquiry practice in their first years of teaching. The abilities and knowledge developed during these first years will continue throughout their careers.

While this research tells us about the inquiry instruction of beginning science teachers, it can also reveal what type of experiences in teacher preparation programs support the use of inquiry among new science teachers. In an analysis of our current data, we were able to determine aspects of teacher preparation that supported the use of inquiry in the classroom. These results are consistent with the literature in the area of science teacher and teacher education (e.g., Abell & Lederman, 2007; Cochran-Smith, & Zeichner, 2005; Richardson, 2001). Some of these areas are:

> **Experiences in classrooms** – The value of working in classrooms to learn how to teach inquiry and how students learn through inquiry is essential. Teachers who learn to teach science during their teacher education program will have the tools to do so in their first year. In our research and the research of others, the more opportunities teachers have for high quality classroom experiences, the more likely they are to implement inquiry in their classes.
>
> **Courses that focus on learning to teach science** – Science teachers have a unique challenge. They must take what is known in science and translate it into something that students can understand. In our study, beginning science teachers enacted more inquiry if they had opportunities to reflect on the process of science and their own science instruction. These courses explicitly have teachers learn how to teach the content in a manner that supports student learning.
>
> **Degrees and certification are linked together** – Teachers who received their certification to be science teachers as part of their undergraduate or graduate degree programs did have a sustained use of inquiry in their first years. Embedding the certification process in the learning of a content area is important in fostering the use of inquiry among science teachers.

In doing this research and in working with science teachers, I have learned that there are additional areas that impact the use of inquiry in the science classroom. These include:

> **Current forms of standardized testing are impacting science instruction** – In NSTA's survey of science teachers (Luft, Wong, & Ortega, 2009), science teachers reported that standardized assessments negatively impacted their teaching of science. One of the unintended consequences of these assessments was the loss of time spent on inquiry in order to achieve the articulated state standards. Assessment of student learning is important, but needs to occur in a way that can provide students with an opportunity to engage in inquiry and that is valuable to the professional development of science teachers. I urge legislators to take this into account.

Supporting a science as inquiry approach requires that education and science faculty to work together – Science and education faculty each have important responsibilities as potential teachers participate in science teacher preparation programs. Science faculty need to use instructional strategies that promote deep understanding of the content and the processes of science. Education faculty need to help new teachers learn how to translate this knowledge into student learning. Teacher preparation programs that are coordinated by both groups of faculty are in a better position to help science teachers understand, enact, and evaluate their use of science as inquiry in the classroom.

Professional development programs are essential in developing science as inquiry instruction among teachers – According to NSTA's survey of science teachers (Luft, Wong, & Ortega, 2009); science teachers reported that they did not have enough professional development opportunities. Science teachers need ongoing opportunities to build their abilities and knowledge in the area of science as inquiry. While these programs can take on different forms, to be the most effective they should focus on content, provide opportunities for active learning and collaboration, and last for at least 80 hours (Garet, Porter, Desimone, Birman, & Yoon, 2001; Supovitz & Turner, 2001).

I have the pleasure of working with teachers, science teacher educators, and others involved in the science education endeavor. Arizona State University has encouraged this work. I am also grateful that I am in contact with the different federal agencies, primarily with the National Science Foundation, but also the Department of Education. In my work with these agencies, I have learned a great deal. I am appreciative that they exist and that they support my work and the notable work of others. I would also like to suggest areas in which I think federal agencies could expand in order to better meet the needs of science teachers. These include:

More support for research in the area of science education – More research is needed in science education. By understanding how students learn science and how teachers can better teach science, our students will be prepared for the challenges of the 21st century. Research is also needed in and across the different science disciplines, and in the informal and formal learning environment.

An emphasis on translating research into practice – Placing research in the hands of teachers is critical if we are going to change how science teachers teach. While projects that provide opportunities for teachers to engage in science are noteworthy, more needs to be done to provide teachers with research experiences in science education and in disseminating the findings of science education researchers. By engaging teachers in science education research and disseminating relevant research to teachers, teachers can explore and learn practices that will improve the learning of their students.

Long term support for science education research is needed – If we are to understand the efficacy of science as inquiry (teaching and learning), then it is important to have support for long-term research projects. In science and medicine there are provisions for long term study, and science education our studies are often confined to short periods of time (a few years). In addition, long term studies and projects increase what we know in science education, and improve science instruction in the classroom.

Consistent funding for federal agencies involved in science education – The National Science Foundation plays an important part in advancing our knowledge in the areas of science education. In order for this organization to continue this important work, increased support for research and dissemination is needed. Every effort has to be made to at least maintain, but really increase, the funding provided to the National Science Foundation for science education research, development, and dissemination.

Mr. Chairman and members of the committee, science educators are very encouraged by the Administration's strong commitment to science education. For instance, we are encouraged by the coordination of the different science initiatives through a central organizing group. This initiative is groundbreaking and will ensure that there is a focused effort to improve science education from schools to institutions of higher education. Ultimately, the future and well-being of our country resides in the science education our students encounter today. And the education our students receive today and tomorrow will be the result of well-developed, coordinated, and adequately funded programs in science education.

I thank you for this chance to testify here today and look forward to answering any questions you may have.

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Mr. MOLLOHAN. Thank you, Dr. Luft.

Dr. Strang.

Mr. STRANG. Thank you, Mr. Chairman, for inviting me to testify about the importance of inquiry-based science education and thank you for supporting the role that NOAA, NSF, and NASA play in improving science education. You can be proud of their work that improves the lives of young people, provides assistance to teachers, and strengthens our workforce.

If I leave you with one message, it is science agencies must play a leadership role in the improvement of science education. Achieving science literacy for all Americans and preparing future scientists requires direct involvement from today's scientists. Science agencies must have the mandate and funding to devote significant resources to science education.

I am Associate Director of Lawrence Hall of Science, University of California, Berkeley. LHS is a national leader in the development of K–12 inquiry-based science and math instructional materials. One in five children in the U.S. uses curriculum materials developed at Lawrence Hall of Science.

I am also Director of a NOAA Office of Education sponsored project, the Ocean Sciences Curriculum Sequence for grades three through five. This grant created a partnership between the LHS Center for Ocean Sciences Education Excellence and Rutgers University to provide students with inquiry-based experiences in ocean sciences. These materials will become the most widely used elementary ocean sciences curriculum nationwide. They were developed by science educators, scientists, and educational researchers, tested by the developers in local classrooms in Berkeley, then field tested by 70 teachers nationwide to ensure their effectiveness and broad applicability. We are now analyzing the very positive field test data to revise the final version of the materials.

My written testimony provides more information about those materials, including our evidence of their effectiveness. But this project would not have been possible, however, without previous strategic investments by NSF and NOAA to build on and change the landscape of science education that has made a project like mine possible.

For most of my career, marine education has resided at the distant margins of K–12 science education. Understanding the ocean is critical to the health of our planet. Climate change, ocean acidification, extinction, hurricanes, tsunamis dominate the news. California alone has a $43 billion ocean economy. Yet, ocean topics are idiosyncratically missing from national and state science standards.

The U.S. Commission on Ocean Policy reported that the absence of ocean sciences in schools has resulted in a generation of Americans ignorant of the importance of the ocean, placing our economy, environment, and national security at risk.

So in 2002, the NSF Division of Ocean Sciences invested $3.5 million to establish a national network of Centers for Ocean Sciences Education Excellence or COSEE. I am the Director of one of those centers.

COSEE has coalesced and elevated ocean sciences education by engaging scientists and science educators in mutually beneficial partnerships. Ocean scientists themselves believe that education is so critical they now devote their research dollars to the endeavor.

In the early days of COSEE, we first began to discuss creating an ocean literate society by infusing more ocean topics into the K–12 science education standards.

Then in 2004, the NOAA Office of Education made a strategic investment, just tens of thousands of dollars, to convene meetings between leaders of COSEE, NOAA, National Geographic Society, the National Marine Educators Association, and College of Exploration to define ocean literacy and the few ocean concepts that should be in K-12 science standards.

The result was the publication of this brochure that describes seven big ideas that all twelfth graders should understand about the ocean. This ocean literacy brochure is a transformative consensus document. There have been nine conferences in three countries devoted to it. It has resulted in the publication of a high school textbook, another high school course, several museum and aquarium exhibits, including here at Sant Ocean Hall at the Smithsonian, several lecture series and web sites. Several states have incorporated some ocean concepts into their standards as a result and this is the new context that has been created for the development of our ocean sciences curriculum sequence.

NOAA and NSF funding brought coherence and prominence to a once marginalized domain of science education. Their involvement ensures that science education keeps up with the fast-moving world of scientific discovery.

Public understanding of science leads our young people to be creative, thoughtful decision makers and is a key to the improvement of our environment, economy, and quality of life.

Thank you, Mr. Chairman and all the members of the Committee, and please continue to support science education within NOAA, NASA, and NSF.

[The information follows:]

Testimony to the House Appropriations Committee
Subcommittee on Commerce, Justice and Science
February 4, 2010

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Introduction

I would like to begin by thanking you, Mr. Chairman and members of the Committee, for inviting me to provide testimony about thc importance to the nation of inquiry-based science education. I would like to thank you in particular for your previous support for the role that science agencies such as NOAA, NSF and NASA play in promoting and improving science education in the United States. I believe you can be vcry proud of the work that those agencies arc doing on a daily basis to improve the lives of young people, to provide assistance to teachers, and to continually improve the quality of our future workforcc. It is my sincere hope that you will continue and even increase support for the education programs of these agencies. If I leave you with only one message today, it is that science agencies such as NOAA, NSF and NASA must play a leadership role in the improvement of science education. The type of high quality science education that is required to bring about science literacy for all Americans and to prepare the next generation of scientists depends on the direct involvement of today's scientists. Therefore science agencies must have the mandate and the funding to devote significant intellectual and human resources to the endeavor of science education.

I am the Associate Dirctor of the Lawrence Hall of Science at the University of California, Berkeley. I have happily worked there since 1991. **Lawrence Hall of Science (LHS)**, the university's public science center, is a national leader in the development and support of science and mathematics instructional materials for grades preK-12. LHS creates programs, tools and approaches that are replicated, scaled up and disseminated nationally. LHS provides professional development to over 20,000 teachers and school administrators each year, and one in five children in the U.S. uses instructional materials developed at LHS. I invite you to watch a short video about LHS at http://www.lawrencehallofscience.org/about.

NOAA-Sponsored Ocean Sciences Curriculum Sequence, Grades 3-5

I am here today to share with you a NOAA–sponsored project that I direct, our first early indications of its effectiveness, and how it fits into a larger constellation of inquiry-based science education reform efforts supported by NOAA, NSF and NASA, and carried out by institutions such as Lawrence Hall of Science. The project I would like to share is the development of an *Ocean Sciences Curriculum Sequence for Grades 3-5,* funded by the NOAA Office of Education, Environmental Literacy Grants program. This grant created a partnership between the Lawrence Hall of Science Center for Ocean Sciences Education Excellence, Rutgers University and a curriculum publisher, Carolina Biological Supply Company. The project addresses the critical need to provide students with inquiry-based experiences related to the big ideas in ocean sciences. We know that nationwide, even in coastal states, despite the important role that the ocean plays in driving earth systems and influencing our history, culture and economy, concepts about the ocean are not commonly taught in grades K-12. This project will create an unprecedented Ocean Sciences Curriculum Sequence for Grades 3-5 that will provide students with 25 hours of instruction about ocean concepts that are aligned with state and national science education standards. It is anticipated that this new Sequence will become the most widely used ocean-focused science education curriculum nationwide at the elementary level. The materials will provide teachers with a standards-based tool for teaching basic science using the ocean as a compelling integrating context. The materials will be grounded in current research on teaching and learning and designed to connect to the *National Science Education Standards, Ocean Literacy: The Essential Principles of Ocean Sciences K-12*, and to a large sample of state science standards. The activities were developed with rigorous input from a team of research scientists, science educators and educational evaluators and researchers. They were thoroughly pilot tested by the developers in local classrooms in Berkeley, California, then field-tested last fall by 70 teachers nationwide to ensure their effectiveness and broad applicability. We are just now analyzing the data we received from teachers and students during the field test in order to revise the final version of the materials. The finished product will include print materials for teachers, with inquiry-based learning activities, a multi-media DVD, student readings and data sheets, curriculum-embedded assessments, and commercially available materials kits that will allow the materials to be adopted by whole school systems and/or states. No comparable ocean sciences curriculum materials are currently available.

I mentioned that the materials we are developing engage students in the process of inquiry. I'll discuss in greater depth later in my testimony what I mean by "inquiry," but for now, let me provide you with an example from the Ocean Sciences Curriculum Sequence for Grades 3-5. One of the most important concepts that we want students to understand is that, "Most of Earth (about ¾) is covered by the ocean." This concept is important because it underlies students' subsequent more abstract understandings that the ocean is a major influence on weather and climate, that most of the oxygen on Earth was produced in the ocean, that most of the living space on Earth is in the ocean, that most major groups of organisms live only in the ocean, that most rain comes from water that evaporated from the ocean, etc. It seems like a straightforward concept, "Most of Earth is covered by the ocean." Straightforward, that is unless you're a 9-year old who has been living on land your whole life and staring at classroom wall maps showing Mercator projections that greatly distort the continents which are always shown in bright colors. We have learned that simply telling students that most of Earth is covered by the ocean is not enough to undo their lifetime of contradictory experience. In the very first session of our curriculum, we have students discuss with a partner how much of Earth they think is covered by land versus water. Then each pair explores a small inflatable globe to look themselves for evidence to answer that question. They try to trace a path on land around the planet and then try to trace a path on the ocean around the planet. They come up with their own forms of evidence, like how many USAs it would take to fill the Pacific Ocean. Finally, we have students collect some data that they can use as evidence. They toss a larger inflatable globe around the room and count the number of times that the right index finger of the catcher is touching land versus water. Inevitably, the data provides evidence that about ¾ of Earth is covered by the ocean. Students write in their notebooks about what the evidence seems to indicate, and how the evidence has helped them to change or support their own personal ideas.

This example is not representative of the most "open" forms of inquiry in which students generate their own questions, develop their own experiments and the criteria for their experimental design, gather and analyze evidence and draw conclusions. But it is inquiry nonetheless, and remember, our materials are designed for 8-10 year olds. The globes activity may not seem like rocket science but here are some of the comments we received from teachers in our field test study. I am including a wide range of comments to open-ended questions so that Committee members will have a sense of the flavor the feedback we received from teachers in extremely diverse socioeconomic, geographic an educational settings:

Huge! Plus, if I had any kids not sure about science before, they have all changed their minds!

This activity had a great impact. It was engaging and the kids were fascinated by how many more of their fingers actually touched water. This was true evidence in their eyes and that is what counts!

it worked well. It gave them a kind of mathematical proof that they needed in order to have a concrete experience.

The recording on the chart reflected what we had already found out so it was a fun way to review and collect more "evidence". VERY effective!

My students loved this activity. We actually performed this twice to see if our results were similar. This was a great way to show evidence of the earth's surface being covered mostly with water.

It was a huge eye opener for them. It made the abstract fraction more real.

It was key because it gave data and evidence to the 70/30 fun fact.

The globe toss was great for the students that needed kinesthetic/hands-on to grasp the concept of the vastness of the ocean.

The hands on globe, the key concepts, and the notebooks really helped to teach the unit. The students will remember this material and be able to use it in the future. I think this also helped them become good thinkers.

It was a good session, I think it helped me to realize that the students have a hard time realizing that they live on a planet, continents, country etc. Something that I assumed they knew.

Evaluating the globe as an example of a model and why models are used in science was effective. Also finding evidence to support more ocean on the Earth than land. Students already knew there was more ocean but challenged by finding evidence to support it. The Global Toss worked very well and was fun!

The globes for student use was extremely effective in showing students the comparison between the globe and Earth. They were amazed that we found more inaccuracies than accuracies. I really enjoyed seeing my students think about whether the Earth should change to being called Planet Ocean and coming up with evidence from the lesson to back up their reasoning.

I think my students have been exposed to the "right" answers but I think they are being exposed to a new way to think about them in this material.

They genuinely thought there was more land than water on the Earth and were surprised that they could not trace a land path around the world but could trace a water path.

They already knew the earth was mostly covered with water but to have the evidence was a powerful addition!

The students believed that the Earth was covered mostly by land because that is what they see each day.

Some kids actually thought different states/countries were in different colors like the model (globe). One thought the words naming the places would be visible from space. I showed them a globe that was more topographical instead of political and I think that helped.

In later instructional sessions in Unit 1, students learn about how scientists at Rutgers University are using autonomous underwater gliders, powered by changes in water density, to collect enormous amounts of never-before-available pressure, salinity and temperature data. One underwater glider just recently completed the first unmanned crossing of the Atlantic Ocean from New Jersey to Spain. Our 3rd through 5th grade students can now use real data collected by RU 27, The Scarlet Knight, to map pressure and temperature changes all the way across the Atlantic. This is another form of inquiry, as students conduct what we call, "secondhand investigations," that is, they use and analyze data that was collected by someone else.

At the end of each teaching session, we surveyed each teacher involved in the field test to obtain comments and feedback like those above. In addition, we also administered pre and post tests to the students in the field test classrooms. While further research is necessary, we have early indications that while all students improved over the course of instruction, lower performing students show especially strong gains when using the materials. This indicates that the materials have promise for helping to close the "achievement gap." Below are pre/post assessment scores for Unit 1 only (Unit 1 is comprised of eight hours of instruction).

Ocean Sciences Curriculum Sequence Grades 3-5, Unit 1
Field Test Feedback Digest

Student Assessment Results

Students showed significant science content understanding on ALL questions on summative assessment!
Students in lowest-scoring percentile had largest gains!
Multiple choice items:

Content of item	Pre-test correct	Post-test correct	Gain	Gain by lowest-quartile students
One connected ocean	0.61	0.88	0.27	0.45
Shape of ocean floor	0.4	0.94	0.54	0.72
Which parts of ocean move?	0.55	0.73	0.18	0.34
Pattern of temperatures with depth	0.6	0.92	0.32	0.48
Causes of ocean movement	0.34	0.6	0.26	0.31
One connected ocean (pollution)	0.47	0.71	0.24	0.4
Percent of Earth covered in ocean	0.7	0.95	0.25	0.51

Largest gain in shape of ocean floor (1 item)
Smallest gains in movement of ocean (2 items)

Constructed response item- "What would you say if someone said the ocean was layered? Would you agree? Please explain your answer."
Scored on a scale 1-4:
1=no, not layered
2=yes, layered, but no explanation
3=one way layered
4=two or more ways layered

	Pre-test	Post-test
Percent scoring 3 or 4	50.8%	76.2%
Percent scoring 4	24.1%	58.0%
Number mentioning temperature	34	96
Number mentioning light	11	22
Number mentioning salinity	3	14
Number mentioning pressure	3	7

By next year at this time, the Ocean Sciences Curriculum Sequence, Grades 3-5 will be readily available for widespread adoption by school districts nationwide. These materials will also be available to individual interested teachers, but they have been designed with school district adoptions in mind so that they will quickly reach the large, mainstream population of teachers who are bound to use their state approved and district adopted curriculum. I'm pleased to let you know that in January 2010, we also received support from NOAA Office of Education to develop an Ocean Sciences Curriculum Sequence for Grades 6-8. We have already begun the development of this complementary project.

Space Science Sequence, Grades 3-8

The Ocean Sciences Curriculum Sequences are modeled after work that my LHS colleagues have done in the NASA supported, "Space Science Sequence for Grades 3-8" published in 2009. George "Pinky" Nelson was a NASA Astronaut from 1978-1989 and flew on three shuttle missions. He is Director of Science, Math and Technology Education and Professor of Physics and Astronomy at Western Washington University. In his Foreword, he wrote: "My fantasy is that every grade school and middle school will adopt the Space Science Sequence and provide teachers with the professional development and other support to ensure that it is well used. I will use it with preservice teachers in my university as an example of the new generation of curriculum materials...I look forward to the time when students arrive in my astronomy classes at the university with the knowledge and skills taught through these materials. It will change the way I teach because students will arrive prepared to take the next step toward even deeper understanding and appreciation of the Universe."

Lawrence Hall of Science and Inquiry

These curriculum development projects are only two out of dozens of teacher professional development, curriculum development and exhibit development projects currently going on at Lawrence Hall of Science. Since it opened in 1968, LHS has continually had a tremendous impact on the field of science education. In those early years, UC Berkeley Physicist Robert Karplus developed a model of optimal learning called the Learning Cycle that he used as a framework for the development of one of the first and most successful hands-on, kit-based science programs in the post-Sputnik era, Science Curriculum Implementation Study (SCIS). Today, the LHS Full Option Science System (FOSS) is the leading elementary hands-on science program in the country. Currently in development is what we believe will become the science program of the future, Seeds of Science, Roots of Reading, that is designed to synergistically integrate science with reading and writing instruction. SCIS, FOSS, Seeds of Science and many others over the last 42 years were created with support from the National Science Foundation. Still others over the years have been funded by NASA, and more recently by NOAA.

LHS and a handful of peer institutions around the country with support from federal science agencies have led the way in defining and promoting approaches to teaching science that engage students in doing science, making their own first hand observations, thinking like a scientist and developing scientific habits of mind, such as providing explanations of the natural world that are based on evidence. Our approach provides students with opportunities to engage in respectful discourse, to think critically and to examine alternate evidence. Ultimately, we want all students, not just future scientists, to be empowered to ask their own questions, and be able to puzzle out tentative answers that help them to understand the world and improve their own quality of life. These approaches are collectively described as inquiry-based science education.

There are many definitions of inquiry. The National Science Education Standards from the National Research Council of the National Academy of Sciences describes inquiry this way:

"...Inquiry is an active learning process - something that students do, not something that is done to them." (p.2)

"...Inquiry into authentic questions generated from student experiences is the central strategy for teaching science." (p.31)
And yet, NSES also states that "...this does not imply that all teachers should pursue a single approach to teaching science." (p.2) There are many levels of inquiry-based teaching from "partial inquiry" to "full inquiry." (p.143)

"Essential Features of Classroom Inquiry:
Learners are engaged by scientifically oriented questions.
Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
Learners engage in discourse to justify and compare their proposed explanations."
(Inquiry and the National Science Education Standards, p 25)

The Exploratorium in San Francisco says:

"Good science education requires both learning scientific concepts and developing scientific thinking skills. Inquiry is an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and testing those discoveries in the search for new understanding. Inquiry, as it relates to science education, should mirror as closely as possible the enterprise of doing real science. The inquiry process is driven by one's own curiosity, wonder, interest, or passion to understand an observation or to solve a problem."
(http://Exploratorium.org/ifi)

There is a growing body of research literature that confirms the effectiveness of inquiry-based science instruction. The literature is typified by a paper recently published in the Journal of Research in Science Teaching entitled, "Inquiry-based Science Instruction—What Is It and Does It Matter? Results from a Research Synthesis Years 1984 to 2002" (Minner, Levy, Century, 2009). The abstract follows:

"Abstract: The goal of the Inquiry Synthesis Project was to synthesize findings from research conducted between 1984 and 2002 to address the research question, What is the impact of inquiry science instruction on K–12 student outcomes? The timeframe of 1984 to 2002 was selected to continue a line of synthesis work last completed in 1983 by Bredderman [Bredderman [1983] Review of Educational Research 53: 499–518] and Shymansky, Kyle, and Alport [Shymansky et al. [1983] Journal of Research in Science Teaching 20: 387–404], and to accommodate a practicable cutoff date given the research project timeline, which ran from 2001 to 2006. The research question for the project was addressed by developing a conceptual framework that clarifies and specifies what is meant by "inquiry-based science instruction," and by using a mixed-methodology approach to analyze both numerical and text data describing the impact of instruction on K–12 student science conceptual learning. Various findings across 138 analyzed studies indicate a clear, positive trend favoring inquiry-based instructional practices, particularly instruction that emphasizes student active thinking and drawing conclusions from data. Teaching strategies that actively engage students in the learning process through scientific investigations are more likely to increase conceptual understanding than are strategies that rely on more passive techniques, which are often necessary in the current standardized-assessment laden educational environment."

We know now that inquiry-based science teaching is effective. We know that when we provide the type of instruction that encourages students to think and behave like scientists, they also construct deeper understandings of the complex ideas of science. If thinking like a scientist is to be the "central strategy for teaching science," as the National Academy of Sciences proclaims, then it clearly follows that the nation's scientists and science agencies must play the leading role in improving science education. NSF, NOAA and NASA must be front and center, not peripheral, in determining what and how our students are taught about science in the future.

NOAA's and NSF's Strategic Use of Limited Funds

NOAA and NSF have both used relatively small investments to engage in strategic field-building activities that have had a tremendous impact within the ocean sciences education community.

The ocean defines and dominates nearly everything about our planet. It seems so obvious why understanding and protecting the ocean is so critical to the future health of our planet. Climate change, ocean acidification, extinction, hurricanes, tsunamis dominate the news. And environmental concerns aside, the ocean provides over $43 billion per year to the economy in California alone.

And yet, when the National Science Education Standards were published in 1996, ocean scientists and ocean educators were dismayed that the National Standards contain almost no mention of ocean topics. As a result, none of the states' science standards include much about the ocean, coasts, or watersheds. Consequently, understanding about ocean topics has been ignored in most K-12 classrooms for at least a generation. There were exceptions of course, but without a coherent framework of concepts and messages, these topics remained on the margins of teaching and learning about science. As marine educators, we frequently found ourselves complaining about the absence of ocean concepts in the curriculum, and we were just as frequently asked back, "Well, what about the ocean IS missing? What SHOULD be taught about the ocean." And of course, there was no consensus about what the answer should be. The absence of ocean sciences in schools resulted in a generation of Americans largely ignorant of the importance of the ocean. How could it be that in states like California, Florida and Hawaii, the ocean is not systematically incorporated into the curriculum? Marine education had become marginalized. When it was taught, it was often presented in a very local context: if you live in "coastal community," then of course you might teach a little about your local area, but this resulted in an idiosyncratic presentation of ocean concepts. So, there grew a perception that marine educators were neither on the cutting edge of scientific discovery nor on the cutting edge of innovation in pedagogy.

In 2002, the NSF Division of Ocean Sciences invested about $3.5 million in the competitive establishment of a National Network of seven Centers for Ocean Sciences Education Excellence (COSEE). Each Center is comprised of a partnership between an ocean sciences research institution, a formal education institution and an informal education institution. The mission of COSEE is to "Spark and nurture collaborations among scientists and educators to advance ocean discovery and make known the vital role of the ocean in our lives." I am the Director of COSEE California, one of the first Centers to be established in the National COSEE Network, and now in its eighth year of continuous funding. I can personally attest to how these Centers coalesced and elevated the ocean sciences education community. Much of the authority of COSEE has come from the presence of scientists. Because COSEE arises from a science research directorate at NSF, and not from the Education and Human Resources Directorate, there is a perception that ocean scientists themselves now believe that education is so critical, they are willing to devote their own research dollars to the endeavor. In the early days of COSEE, the Center Directors began to talk about creating an "ocean literate society" by infusing more ocean sciences concepts into the mainstream K-12 science education standards. We quickly realized that we needed to define what it meant to be ocean literate, and what ideas about the ocean are so essential that every student should understand them by the end of high school.

In 2004, the newly established NOAA Office of Education, made a small but highly strategic investment, perhaps just tens of thousands of dollars, to convene a series of online and face-to-face meetings between leaders of COSEE, NOAA, National Geographic Society, National Marine Educators Association and the College of Exploration (a distance learning organization) for the purpose of defining Ocean Literacy and determining what ocean sciences concepts should be in mainstream K-12 science education standards. The result was the publication a year later of a small brochure entitled, "Ocean Literacy: The Essential Principles of Ocean Sciences K-12." The brochure defines Ocean Literacy in the following way:

"Ocean literacy is an understanding of the ocean's influence on you and your influence on the ocean.

"An ocean-literate person:

- understands the essential principles and fundamental concepts about the functioning of the ocean;
- can communicate about the ocean in a meaningful way; and

- is able to make informed and responsible decisions regarding the ocean and its resources"

The pamphlet further describes seven principles of Ocean Literacy or seven big ideas that everyone should understand by the end of high school:

1) Earth has one big ocean with many features.
2) The ocean and life in the ocean shape the features of Earth.
3) The ocean is a major influence on weather and climate.
4) The ocean makes Earth habitable.
5) The ocean supports a great diversity of life and ecosystems.
6) The ocean and humans are inextricably interconnected.
7) The ocean is mostly unexplored.

Each principle is elaborated by a handful of "fundamental concepts," 44 in all, that can be seen at http://www.oceanliteracy.net.

The Ocean Literacy Brochure quickly became a consensus document, a unifying rallying point among ocean scientists and ocean sciences educators. There have now been nine entire conferences in three countries devoted to discussing the Ocean Literacy principles. A new high school textbook has been developed; another high school course is in development; museum and aquarium exhibits (including the Smithsonian's new Sant Ocean Hall) have been designed; lecture series and web sites abound; several states have incorporated ocean concepts into their science or environmental education standards; and of course the Ocean Sciences Curriculum Sequences (described above) are underway. Most Requests for Proposals released by NOAA now require applicants to address the Ocean Literacy Principles as a criterion for funding; and the same is true for RFPs coming from NSF Geosciences Directorate. The Ocean Literacy Brochure has certainly changed the way we think about the importance of providing children with opportunities to learn about the ocean. The process was so successful at bringing together scientists and educators to think deeply about the most important concepts within a domain, that it has been replicated several times. Similar brochures have now been published describing Atmospheric Literacy (supported by NOAA), Climate Literacy (supported by NOAA) and Earth Science Literacy (supported by NSF). These efforts have greatly helped to clarify and prioritize the big ideas in domains of science that are rapidly growing in importance and prominence. I have no doubt that these consensus documents will greatly influence the content of the future "Common Core" science standards now under development.

While the Ocean Literacy principles describe what students should know by end of Grade 12, a new, much more elaborate guidance document is now in press, *The Ocean Literacy Scope & Sequence for Grades K-12*. The Scope & Sequence describes what students need to know about each principle in Grades K-2, 3-5, 6-8 and 9-12. The impact of this document has not yet been felt (publication will be in mid-February), but it will no doubt be significant. The NOAA Office of Education has stepped forward with funds for its publication as a "National Marine Educators Association Special Report on Ocean Literacy Featuring the Ocean Literacy Scope & Sequence K-12." I have attached with this testimony electronic copies of both the Ocean Literacy Brochure and the DRAFT NMEA Special Report on Ocean Literacy.

NOAA and NSF funding for ocean sciences education has been highly complementary, and together has brought coherence to a once fractured and marginalized domain of science education. The small amounts of funding provided have been leveraged by building on lessons learned more broadly in science education through much larger investments from NSF Education and Human Resources Directorate. From a personal perspective, I can certainly say that NOAA and NSF have greatly enhanced the efficacy of my work and of the work of many of my peers and colleagues across the country.

In conclusion, I would like to repeat my thanks to you, Mr. Chairman and members of the Committee, for your past and continuing support of science education. I believe there are few areas in our society more important than public understanding of science, technology, engineering and mathematics. Widespread understanding of these areas which leads our young people to be creative and thoughtful decision-makers, is a key to the future health and prosperity of our economy, environment and quality of life. I would like to encourage your continued support of the science education efforts within NOAA, NASA, NSF and our other great science agencies.

SUPPORT FOR INQUIRY-BASED INSTRUCTION

Mr. MOLLOHAN. Thank you. Thank both witnesses.

Today we are really focusing on and learning more about STEM education, the status of STEM education. Yesterday I asked one of the witnesses, "Is there any credible debate out there as to the benefit of inquiry-based education to teach STEM courses?" And the answer was no.

And then it became clear as the hearing went on, when you talked to the witnesses, that while there may not be a debate at some level about the superiority of inquiry-based education for these disciplines, there certainly was a lot of difficulty in migrating that technique out through the real educational systems across the country, which seems to be a bit of an irony or at least a tragic problem.

If there is really no debate that inquiry-based education is by far the superior way of teaching young Americans about science, then why is it not being embraced universally across the school districts of the country?

Dr. Luft.

Dr. LUFT. You know, that is a really good question. We do see that there are more and more good inquiry curricula that are being put in schools, but I think you have to realize that this curriculum costs money. And schools, especially right now, are making choices about what they are going to fund. Over the years, they have made these choices, too. So it is acquiring the curriculum; it is also supporting the curriculum.

So for the teachers that I work with in the Phoenix area, many of them have the FOSS kits, but some of them are in districts that may not have a science coordinator who can help provide professional development for the teachers to support them in using these kits appropriately. If they get the kits, learning how to use them in ways that are really conducive to developing understanding is critically important.

I think another concern on the teacher education end, which I am comfortable to speak about, is that we really need to work in the science education community on who knows this. We need to work to help our teachers understand how to use the kits when they go into the schools. But sometimes there is a disconnect between the materials and supplies we have at the University versus what is in the local schools.

So while there is great curriculum, that curriculum varies by district, and it also is supported in ways that are not equivalent. Some districts may be able to or have a science coordinator and other districts may not. So supporting that enactment is very difficult.

Mr. MOLLOHAN. Well, I would like to get down to the detail of that a little later.

But, Dr. Strang.

Mr. STRANG. Mr. Strang.

Mr. MOLLOHAN. I am sorry.

Mr. STRANG. It is okay.

Mr. MOLLOHAN. It is Dr. on your card there.

Mr. STRANG. Oh. Well, I appreciate the honorary degree.

Mr. SERRANO. We give everybody titles.

Mr. HONDA. No money, but——

Mr. SERRANO. Dr. Mollohan.

Mr. STRANG. I agree with everything that Dr. Luft said and I think resources and money are certainly an issue.

But aside from the current budget crisis that, for instance, California schools are in, I think there is another issue that is just as profound with the implementation of inquiry in our science programs and that is the issue of instructional time, not so much money.

We are finding in school districts across the country, but especially in California, that even after the adoption of the FOSS Program or other inquiry-based materials that because of the emphasis on accountability and English language arts and mathematics at the elementary level, that elementary science programs have been virtually dismantled.

In the San Francisco Bay area, the Lawrence Hall of Science did a study in 2008; we found that the average elementary school teacher in the eleven Bay area counties spends about an hour and 15 minutes a week teaching science. And we know that most of that time is spent in grades four through six or four through five. So we figure that at the K through two or K through three levels, teachers are spending maybe 30 minutes a week teaching science, and you cannot do inquiry in that amount of time.

So while we know, and I think most teachers today understand the importance of inquiry and the difference in student understanding when they present concepts using inquiry versus when they present them through other direct instruction methods, even though teachers understand that, they are in this constant conflict over managing the time of their instructional day.

SUPERIORITY OF INQUIRY-BASED INSTRUCTION

Mr. MOLLOHAN. If I might. The witnesses yesterday made that point that inquiry-based, while most people, and you just said while most people acknowledge inquiry-based, is superior, in effect, you said that. In spite of that testimony yesterday and just for purposes of discussion here, I really wonder about that and that seems to be a real threshold question to me.

As much as people are ringing their hands about America being behind in teaching math and science, if everybody believed, that there was this consensus out there that inquiry-based education is the way to go, then I do not know that we would be having difficulty developing materials here at NOAA and all the other places materials are being developed and trying to get it out on a onesie and twosies basis from bright people who are working hard and really trying to pull the kind of organizations together to get the curriculum and get the teachers taught and then actually support them in the field. I do not think we would be having so much of a problem about that.

So my question really goes to the premise that everybody believes that inquiry-based education is a superior way to educate these young people in science.

Mr. STRANG. I think that there is a growing consensus about inquiry and the effectiveness of inquiry, but alternatively, science education is not a priority. So there are many school districts in

California that are telling us, well, we would have adopted FOSS in the last science adoption year, but we knew we could not do it justice and it is expensive and if we are not going to use it, why would we pay for all those kits? So we just bought the textbooks.

IMPLEMENTATION OF INQUIRY-BASED STEM INSRUCTION

Mr. MOLLOHAN. Okay. Well, if everybody agrees that inquiry-based education is the way to teach science, then we ought to be about how does the Department of Education migrate inquiry-based education like that throughout the country if that is how we ought to be teaching science to youngsters.

Dr. LUFT. So I think this is again a complex problem. We can agree. And I think if you talk to teachers, we agree that science as inquiry is incredibly important, but there are factors that really bear down and constrain the teaching of inquiry, no matter how much we know or how important it is.

And you are right. The testimony yesterday really hit on this hard that the testing and the accountability has constrained the teaching of science as inquiry.

At the secondary level, I have walked into science classes to watch teachers teach, but I have been told the science class is canceled at the secondary level to prepare for testing. The kids were getting skills to take the test, so we are losing a period of time. This is huge.

But the other piece is communities. I think when we have lost a lot of funding for the professional development of teachers, when that funding went away, teachers did not have the support or the communities to constantly be thinking about their practice and enriching that practice.

Mr. MOLLOHAN. Thank you. We will follow-up.

Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman. Let me just pursue this a little bit more.

How is it that we define inquiry and why is it only confined to STEM and why do we focus only on children when it is the teachers that teach?

Are we focusing enough time on the teachers to be able to do that across the curriculum instead of just focusing on STEM, because you have instruction and content, process and concepts? You have deductive, inductive approaches, too, but process seems to be where inquiry is.

So I was wondering, combining all these questions in one, do you have some sort of idea what it is that people see that is going on because I really do not see a constraint.

Dr. LUFT. So I think you are asking me two questions—that is what I am hearing. I think you are asking me what is it that makes science as inquiry unique. First off, that——

Mr. HONDA. I am asking you what is inquiry?

Dr. LUFT. What is inquiry?

Mr. HONDA. What is teaching inquiry?

Dr. LUFT. Yes.

Mr. HONDA. I mean, if a teacher cannot teach it, how can they expect it? Are we sure that the teachers are being instructed on how to do that?

And if it is only done in four and five, it seems to me that K through 8 seems to be a strand of instruction when you do inquiry because we ask our youngsters to check for understanding. We inquire, and that is something that youngsters can mimic from teachers when we do that. Am I off base or what?

Dr. LUFT. Do you want to—this is——

Mr. STRANG. Yeah. Well, there is a variety of——

Dr. LUFT. There is a variety——

Mr. STRANG [continuing]. Directions here. Yeah.

Dr. LUFT. So I think that we are really trying to, if I understand this, I think we are really preparing our teachers to do science as inquiry. And in the research that I do, what we really see is that it is constrained when they first go into the school.

When they graduate from preparation programs, I think they know and they understand what science as inquiry is and they want to practice this. But when they first hit the schools, they can be constrained in the environment if there is not adequate support or if their other colleagues are not engaging in this. So it is not—it may not happen for teachers.

Mr. HONDA. It seems to me that through any subject matter, one can use the inquiry method and teach youngsters by modeling that. And it is not only— unless you are asking— trying to teach the scientific method in going through those steps and then you do the observation, note taking, and then you——

Mr. STRANG. Right.

Mr. HONDA. You still can do that, I think, in other instructional areas where—in an integrated approach to a curriculum and teachers get together trying to figure out how we are going to get this as an outcome.

And I understand time on task, but I wonder whether we really use enough time to teach and to rest assured that we are, in fact, agile enough to understand how to use this in other curricular areas.

Mr. STRANG. Right. So I will respond with an example. I think there are many things that are unique about inquiry in science, about science inquiry. And at the same time, we are doing quite a bit of work at the Lawrence Hall of Science right now trying to understand the relationship between science inquiry and literacy skills. And we think about good thinkers in language arts classrooms as being inquirers into text and inquirers into ideas. So there is some overlap there.

We are in the process of developing a new set of materials that I think by the time of the next round of science adoptions will be available on a large scale. The new program is called Seeds of Science, Roots of Reading and it explores the synergy of the integration between science and literacy and how students very consciously and directly thinking about the similarities and differences in how they investigate phenomenon versus how they investigate text and ideas.

Mr. HONDA. So you are saying that there are these skills that build upon each other?

Dr. LUFT. Yes.

Mr. HONDA. There is a hierarchy of skills in inquiry?

Dr. LUFT. That is right. And that there is a curricular economy in integration that could help to overcome some of these instructional time issues that are such a challenge at the elementary level.

So we have students that are doing investigations in their science class and reading text, reading student reading books that are written in such a way that they elaborate the concepts that the students are investigating and teach reading skills at the same time.

Mr. HONDA. But you are assuming that they are using a textbook as a guide rather than a teacher's insights in understanding the hierarchy of these skills and incorporating that as she or he teaches and leads youngsters through a process?

Dr. LUFT. Yes, absolutely. So teacher preparation and professional development and the skilled nuanced teacher are essential, but also good materials that allow a teacher to follow along through a teacher's guide that embodies inquiry is also very important.

Mr. HONDA. Well, that is my point, Mr. Chairman, that if the teachers only depend upon the textbook and they are not taught to have the insights and integrate within themselves that skill and understanding of where youngsters are and how to move and weave this thing, we may not be paying enough attention to where the problem really lies. And it is us adults assuming that we can teach to those things because a scientist is skilled in what they do. And we just all of a sudden understood the contact between physical and biologic kinds because we are able to get down to the nano scale. We have other inquiries that we start to develop, but the basics are still there.

I challenge what you guys are saying about instruction and only gearing inquiry to the area of STEM.

Dr. LUFT. Maybe I can take another—so science as inquiry is very unique to science and it is different. Mathematics is problem solving. And in mathematics, a student in math would never be able to look at a phenomena as an advanced mathematician does and create the formulas or the proofs that are needed to explain the mathematics. But in science, we are really interested in understanding the natural world. And it is about making explanations about that natural world using argument, using evidence, collecting data, and these are unique pieces to science as inquiry and they are not necessarily transferable to some of the other areas by the nature of the content with which they are associated.

Mr. HONDA. But is not math a language of science?

Dr. LUFT. Math is.

Mr. HONDA. It is a tool of science. And, I mean, if you want to get that way, you can send a youngster through a neighborhood and over time, they can figure out the facts and say every time I go down the street, I am going to get hit, so I have to figure out another way of getting around it.

Intuitively they have ways of looking at a problem and solving it and we just have not figured out how to transfer some of that——

Dr. LUFT. Right.

Mr. HONDA. [continuing]. Just trying to have us reshift our thinking. And then, Mr. Chairman, if I could just close with this one comment.

We have something like a little over $2 billion invested in I think 120 STEM education programs by 12 agencies, none of which are coordinated. Do you think that—you know, I have a bill called ESTEM where we asked ourselves to gather all this information. We have a repository where we can take advantage of the information that is gathered by all these grants and research.

Is that a need as far as having a place where we can go and get the information that has already been figured out but never been shared or coordinated or have some cohesion about what we have already?

Mr. STRANG. Well, coherence is good. So the more coordination that can be achieved through the science agencies, the better. And different science agencies are engaged in different fields of scientific discovery and so have different new material that gradually should become part of the science education curriculum nationwide.

So there is a role for the separate agencies to be exploring and discovering in their respective domains. And then, of course, education efforts should be coordinated with the goal of coherence. And we are hoping that the common standards, the common core will help to achieve some of that coherence in the near future.

But a lot has changed in the world of science discovery since the National Science Education Standards were published in 1996. So clearly we need some updating of what we think students should know and understand by the end of twelfth grade.

Mr. HONDA. So we do not have anything that does that right now?

Mr. STRANG. Correct.

Mr. HONDA. Do we need one?

Mr. STRANG. One what?

Mr. HONDA. To do that function that you just described.

Mr. STRANG. One agency or one what?

Mr. HONDA. Way. I mean, should we spend some time to do that? Is it worth the time?

Mr. STRANG. Sure. I mean, I think that coordination is important and that the discoveries that are coming out of NOAA and NASA and NSF have to be looked at in the context of what are the salient ideas that kids need to know in order to have access to these new discoveries as adult learners.

Mr. HONDA. I would ask if you would not mind just reviewing that bill and see if there is a—just getting your reaction, professional reaction.

Mr. STRANG. Of course.

Mr. HONDA. Appreciate it. Thank you.

Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Honda.

A recess we have. I apologize to the panel. It is part of the process here. We have about five votes and a recommit which means we are probably recessing for about a half hour.

Mr. STRANG. Okay.

Mr. MOLLOHAN. And we will be voting down there and so thank you for your patience.

Mr. HONDA. Thank you.
[Recess.]

ASSESSING STUDENT INQUIRY

Mr. MOLLOHAN. The hearing will come to order. We will continue the hearing by calling up Mr. Schiff.

Mr. SCHIFF. Thank you, Mr. Chairman. First of all, I want to say, Berkeley, we have a witness from Cal, I mean, where are the standards, Mr. Chairman? What, what—sorry, it is the Stanford in me coming out. But I was reading your written testimony, and plainly if you look at the map here you can see that the land is far more than 30 percent. I mean, look at that. Just look how big Antarctica is. It could not possibly be less than 50 percent land.

Thank you both for coming today. I concur completely with the thrust of your testimony in terms of inquiry-based teaching. And when I think back about my high school years in particular the lessons that stand out to me were very inquiry-based, were very kind of innovative and not rote memorization. I had a wonderful teacher, for example, who gave us a test, a pop quiz that was impossibly difficult. And we were all in a panic because it was horribly impossible. And we were failing it. And then he revealed afterwards that this was the same exam they gave African Americans in order to qualify to vote. It was the polling exam. And it was a very clever way of teaching us that the exam was meant for them to fail. And it was a lesson I remember to this day because of the innovative way it was taught. I mean, had they just said memorize the fact that they used to require African Americans to take this test because they wanted them to fail and not be able to vote, I would probably never have remembered that. But at one point he would assign more and more homework and more and more homework. It got impossible to do and we got together as students and protested. And he was teaching us about collective bargaining. It was really quite wonderful.

And the question I have is, you know and I think this is pertinent in light of the fact that we are looking at reforming No Child Left Behind. There are some laudatory goals in No Child Left Behind. We want ways to measure student achievement. We want to be able to compare school to school. We want parents to be armed with information so they can say to schools similarly situated socioeconomically, et cetera, why is one doing so much better than the other? The parents at the school not doing so well can say why are our kids not doing as well? How do you measure achievement in an inquiry-based learning environment? If you are not teaching to the test, how do we measure, how do we hold accountable? What are your thoughts on that?

Mr. STRANG. Well, there are assessment tools available that look at the requisite inquiry skills and I think those tools are available. And again, the question is are the results of those assessments, when we look at them and find out how students are doing, are those results valued compared to results of content knowledge, understanding, and even more importantly reading and math skills? So I think the tools exist. They are a little bit more complicated to administer. They are more like performance tasks, and open ended constructive response items on assessments. They tend not to be multiple choice, scannable tests. But they certainly exist and are available for school districts that want to use them. The question is, what is the value of using them if nobody cares what the results are?

CREATIVITY AND INNOVATION

Mr. SCHIFF. It has always been considered a strength of education in the United States, and maybe part of our culture also, this propensity we have to kind of question things, not do things by rote, think outside the box. It has been a competitive economic advantage for us vis a vis other countries that have turned out much greater numbers of college graduates. How have we been able to do that? Are we doing less of it now because we are, you know, sort of teaching to the test, and going to a more rote system? What are other countries doing? Is China teaching with an inquiry-based system, or Japan, or Germany, or India? How do we compare? Are we losing our advantage?

Dr. LUFT. I think the U.S. education system is the best in the world. And it gives a lot of graduates, we can say this at the university level, people come from all over the world to study in our system. So this system is amazing in its commitment to every student in this country. And we have to realize when we think broadly not all countries are committed to every student. So that is something to always keep in mind.

But I think one thing that is really promising that we are doing in terms of even coming more to a consensus about what we should be teaching in science is we are working to really identify some core standards. And I know the common core is coming up, it is up in English and mathematics, they are working on that, this is promising. And what it brings forward to science are the key ideas and the central ideas that are really important that we need to come around. So we are not trying to teach a lot of things; we are teaching the very few important things really well. And when we look at other countries, that is what we see. We see some very clear expectations of what students are to know and opportunities for those students to learn. But when we do look at other countries too, I want to stress this, in some of the countries we do not see as much inquiry as we are really promoting here. And I think the value behind inquiry is the innovation that it gives this country to be on the front edge of the ability to solve problems and to really think outside the box. This is something that this country has always been dedicated to. And I think our curriculum really supports that. And I am encouraged greatly by thinking about the common standards. I think that will really help move us along greatly.

Mr. STRANG. I will just add that at the Lawrence Hall of Science at U.C. Berkeley we have a fairly constant flow of visitors from Japan, China, Singapore, et cetera. Countries that all score higher than the United States in the international assessments of math and science. And they are coming to the United States, and to California, and to Berkeley in particular, to learn about inquiry. And they are scoring high, their students are scoring higher on their tests. But their students are not engaged in science, and not continuing in science at the secondary level. So they are coming to us to learn about this sort of magic of teaching kids how to think, and how to get excited about the natural world, and how to investigate and puzzle through problem solving and answering their own questions. And I think many of those countries are superb at implementing science education programs, but not very good at designing science education programs. And I think the United States is exactly the opposite. We have this sort of cutting edge, brilliant thinking about the design of programs but we are very challenged at implementing, as we are hearing about today, and providing this inquiry-based opportunity for a large population of students in school districts and states all over the country that have different standards and different assessment tools, etcetera.

Mr. SCHIFF. Thank you, Mr. Chairman.

IMPORTANCE OF STEM EDUCATION

Mr. MOLLOHAN. Thank you, Mr. Schiff. Mr. Culberson.

Mr. CULBERSON. Thank you, Mr. Chairman. The work that you are doing that we are talking about today I think is among the most important things we can possibly do to help strengthen the country in the future. I completely agree with the Chairman about inquiry-based education. And am delighted to see the support that the Committee and the administration have for strengthening the existing programs at NOAA, and the National Science Foundation, and NASA to help teach teachers to do a better job of teaching science and to strengthen these programs at the district and the state level. My only concern is to be sure that if states or districts accept the money that we are not imposing national standards on them. I am a big believer in education is not under the Constitution under the tenth amendment, it is reserved to the states. And that would be my only concern, Mr. Chairman. I am just delighted that you have called this hearing and very, very supportive of this work and this effort. Thank you, sir.

STANDARDS OF LEARNING

Mr. MOLLOHAN. Thank you, Mr. Culberson. Mr. Fattah.

Mr. FATTAH. Thank you, Mr. Chairman. Let me thank the witnesses. I have introduced legislation in support of common core. And I think that the fact that the states and the governors have gotten together and have agreed that there really is not any difference, you know I represent Philadelphia, Pennsylvania, but there is really no difference in algebra in Philadelphia, Pennsylvania and algebra in Philadelphia, Mississippi. I mean, there are really, you know, through a number of analyses we know with a certainty that most of our children do not get the higher order math in the order that they need to receive it to, by direction of the College Board twenty years ago, about where the sequencing of these courses should come. But that is really not happening. It is not happening in Pennsylvania, or in West Virginia. It is not happening in Texas.

I mean, so the fact that children do not, the fact that children do not achieve as well as we would like them to is not really new. In fact, when the Nation at Risk study came out in the 1980's it talked about the dearth of our young people being able to pursue rather science or math. Most of our children in this country are not taught math and science by a teacher who majored or minored in the subject matter. And it is impossible for one to transmit information that they themselves do not have. And I have spent a lot of time looking at some of the challenges, and you know, states have been wrestling with this. The common core, I think, gets at this in a way in which even me and my colleague from Texas can agree since this is a state-driven initiative by individual states who have gotten together to say that we really need to, I think it was President Nixon who said it was a national imperative, that we really do need to make sure that our young people gain an ability to critically think and analyze.

So I want to thank the Chairman. He has done a great deal without notice over the years to promote science and math through the work of this Subcommittee. And there is more that we need to do. And we have problems all the way throughout our system. We have almost, I mean I do not want to be overly dramatic, which is the way it is done here in Washington, but there is a significant absence of native born Americans pursuing terminal degrees in math and science. So that when we talk about, if we looked at the National Nuclear Security Agency, who are handling our nuclear stockpile, as these people are checking out, that is retiring out, and some 80 percent, 85 percent of the workforce is leaving in the next decade, in terms of young people pursuing nuclear physics, and some of these other, you know, needed disciplines, there is going to be no one to even hire that meet the security requirement of being an American citizen to be able to do this work.

So we have to do something. The idea that education is a local prerogative, and that people can decide how dumb they want their children to be, and it is no concern to us if they do not want to provide an education, no that is not true. And that is why in this international competition economically we are getting our clock cleaned by nations that have really devoted themselves to driving math and science through to their young people. And many of these countries, you know India has got a billion people. So, you know, if we have got a much smaller population, and there is some who would like us to have even less of a population, you know, in terms of immigration issues, then we are going to have to be a lot smarter if we are going to compete. You know, and then China has got even more people. And they are ramping up their education system.

So, you know, when Japan was out-competing, out-producing us in engineers, you know, a couple of decades ago, people said, well, it is a much smaller country. You know, it does not really matter, and so on. Now China is out-producing us in the production of engineers and it really does matter. You know? And it really will have an impact.

So I just want to thank you for the work that you are doing. And I want to thank the Chairman for putting a focus on this at the very front end of the work of the Subcommittee as we go forward. Because when we talk, when we are out on the floor talking about jobs it really starts with the work that you are doing. That if we do not do something about this it is impossible for us to be competitive economically and to have the job base that we want to have in this country. So thank you.

SPREADING INQUIRY-BASED INSTRUCTION

Mr. MOLLOHAN. Okay, thank you, Mr. Fattah. We talked a little bit earlier about if there is a consensus among those who really think about these things that inquiry-based STEM education is the best way to proceed. How do you get a broad based consensus, and then how do you get broad based implementation? And is that the crux of the challenge we face? Dr. Luft.

Dr. LUFT. I think it is two-fold. You know, we have to get the information out there. And I think teachers really do agree, again I want to stress it, they do agree that science as inquiry is a great way to teach but they feel incredibly constrained.

Mr. MOLLOHAN. Now you are talking about teachers out in the field?

Dr. LUFT. I am talking about teachers out, and teachers that I prepare. So I work very closely and monitor a lot of what happens in teacher preparation. So across the continuum: pre-service teachers, new teachers as well as experienced teachers. And I think they are excited about inquiry and what it offers. But I think, again, they are very constrained by sometimes the, as we have talked about extensively about here, is the testing that is imposed on them to meet those standards.

Mr. MOLLOHAN. So what are the impediments? Testing?

Dr. LUFT. Testing is a big one. I think also having the fiscal support for getting the materials into the classroom.

Mr. MOLLOHAN. Materials?

TEACHER'S CHALLENGES

Dr. LUFT. Having some personnel that can actually support them, which would be important. Professional development programs that are extensive, so we know, actually the research is pretty compelling that we are looking at threshold hours, they said sixty yesterday, the data I have seen has said eighty. There is some effect, but then when you push up to 160 you start to really get an effect of using inquiry. So——

Mr. MOLLOHAN. And that is retraining the teachers? Reteaching the teachers, 180 hours you are really——

Dr. LUFT. Professional, extended professional development. Yes, yes, I think you are right. Training the teachers. And it is really giving them deep opportunities to learn the content but to also work with their peers. So some of the more compelling work that is coming out is talking about teachers in communities. So as teachers work together to examine students' work they can really see what they are doing, and they can make decisions about what they need to do in the curriculum to enhance the work that they are doing in the classroom. And schools are set up, though, not to give teachers this kind of time. Schools, by the very nature of their construction, do not give teachers enough time to sit and reflect and really understand what their students know. I mean, to do that these teachers would have to pore over the work. They would make judgments about the work, and they would say, well what am I going to do next? And schools do not allow that, because they start at 7:30 in the morning, and these teachers are with these students the entire time until they go home.

Mr. MOLLOHAN. So you really have to do that outside the classroom, and probably outside the school year in some sort of retraining program, and materials and——

Dr. LUFT. But, but yes——

Mr. MOLLOHAN [continuing]. The money to do that, and incentivize teachers to actually come into those programs.

Dr. LUFT. So you are——

Mr. MOLLOHAN. You probably have to work with stipends.

Dr. LUFT. So you are giving them another, I just want to be very clear about this, you are giving them a second job on top of their current job. And I think all of us in our profession, we have, I have opportunities, my university says, Julie, we want you to get some training. We are going to give you two weeks off to go get that. You know? Because it is that important that you bring it back to us. And I think we have to think——

Mr. MOLLOHAN. Is that two weeks off paid?

Dr. LUFT. If it is affiliated with my work——

Mr. MOLLOHAN. Yes. Sure. I mean——

Dr. LUFT [continuing]. They will work with me on it. Yes. Yes. I can work my schedule.

Mr. MOLLOHAN. I think you have to be unapologetic about that, to tell you the truth.

Dr. LUFT. Yes. Yes. No, no. But I am paid by a taxpayer.

Mr. MOLLOHAN. Because there are a lot of teachers out there that they only time they have to relearn is during the summer, and they have got a lot of things to do in the summer.

Dr. LUFT. And it gets worse.

Mr. MOLLOHAN. If this is important.

Dr. LUFT. Absolutely. And it is worse than that. So these guys not only want to improve their practice, they are working with kids and they cannot get the time off during the day to think about it. But say they want to go to a conference to meet with other people who are excited about what they are doing. They cannot get the time off from their district to go to these conferences because the district cannot give them time because they do not have enough subs. So the very barriers, the very barriers that are in place are keeping these teachers from doing the work that they want to do and need to do.

Mr. MOLLOHAN. Yes. Assuming we have got all the right things——

Dr. LUFT. These pieces, yes.

Mr. MOLLOHAN [continuing]. You should be doing. Mr. Strang.

Mr. STRANG. Yes, so I think our schools are set up in a way that we assume that once a teacher is ready to teach that all they need to do is just teach. And none of our jobs are like that, and we are expected to grow, and continue learning, and to interact with our colleagues and our peers on a regular basis. And it takes up a lot of our day each day. And I think we need to rethink the learning and the teaching environment. If we are expecting kids to engage in inquiry, then teachers need to be engaged in their own inquiry, and adult learning, and extending their own practice in the same way that they are expecting their kids to.

And I think there is a tremendous amount of evidence that even with extended teacher professional development, teachers' beliefs and understandings, their knowledge and beliefs, change long before their practice changes. And this is true of all of us, but we observe it very clearly in teacher professional development. That teachers take the pre- and the post-survey. They tell us that, oh my God, this is changing my life. I am going to, you know, I get it, I understand, I am never going to teach the same way again. And we go back into their classrooms a month or two months later, and we observe their lessons, and they are teaching the same way they did last year.

So this is the sort of ongoing professional development that Dr. Luft is talking about, where teachers need to be trying something out in a scaffolded, structured environment, gathering student work, bringing it back, sharing it with colleagues, watching video tapes of themselves teaching, observing their colleagues teaching, and really thinking, how do I know what my kids are learning? How do I know what is in their heads? And when I find out what is in their heads, what is it that I can do to make them turn this way rather than that way? And at what point in my lesson could I have asked a different question, or provided additional experiences, gone back to observing the phenomenon, etcetera, that could have overcome that potential misconception that is building in my kids' heads? And I think, you know, that is challenging, thoughtful work, not to be taken lightly. And it is not just going to a workshop and coming back and, oh I get it, I am different now. It is just as hard in a teaching setting as it is in any of our professional lives, to actually change our practice.

Mr. MOLLOHAN. Sounds like some really good elements for a demonstration project you all are coming forth with, here.

TEACHER PREPARATION IN SCIENCE

Mr. STRANG. Yes. And I want to also just comment on something that Mr. Fattah said about the importance of having people in schools teaching science that have some background in science. And that is a challenge at the secondary level. It is almost an impossibility at the elementary level.

Mr. FATTAH. At the elementary level it does not exist.

Mr. STRANG. Yes. And I think this notion of attracting our best and brightest science students into the teaching profession is very important. And there are many high quality programs, like Dr. Luft's at Berkeley. There is the Cal Teach program that is a teacher preparation program that attracts science students in particular into the teaching professions. There are examples of those things. But broadly across the country there is still a phenomenon in science departments in universities that scientists, faculty, consider it a failure if their graduate students go into teaching. That is considered second, or third, or fourth class. And I think that this reflects the view of the American public of the teaching profession. And that part of our job also is to elevate the teaching profession and make this a desirable, noble job for teachers to pursue, for students to pursue from all different disciplines.

STEM EDUCATION AND THE DEPARTMENT OF EDUCATION

Mr. MOLLOHAN. You all, I bet, interact with the Department of Education?

Dr. LUFT. I have. I have had projects that have been affiliated with the Department of Ed.

Mr. MOLLOHAN. What is the Department of Education doing in this area?

Dr. LUFT. I mean I think this, you know——

Mr. MOLLOHAN. But I mean to facilitate the national adaptation of inquiry-based learning, and the teaching the teachers that needs to happen in order to accomplish that? And getting the materials out that need to accomplish that?

Dr. LUFT. I think one of the——

Mr. MOLLOHAN. Which I want to get into a little bit.

Dr. LUFT. Yes. I think one of the big initiatives that just, I mean you did form, their Math and Science Partnerships were moved to the Department of Ed.

Mr. MOLLOHAN. I am sorry, what?

Dr. LUFT. The MSPs, the Math and Science Partnerships were moved there. So that has been their responsibility, to try to cultivate and support these partnerships. But I think the work, and it is very good work, it is very important work, but I think the coordination that is coming from the science community, or the efforts that are coming from the science community, NSF, those are the pieces of work that are really at the heart of the matter of the materials and of the professional development opportunities.

Mr. MOLLOHAN. Why is Education not doing this? I mean, they are the ones who would know this before we would know it, supposedly.

Dr. LUFT. Are you talking about the Department of Education? Or are you talking about educators? Or——

Mr. MOLLOHAN. I am talking about the federal government. We are an Appropriations Committee, and at the end of this I am going to ask you for some suggestions, guidance on funding. And maybe doing a demonstration.

How you would like to see that happen. We are going to invite you to help us with that. But right now I am asking you, why is the Department of Education not, if there is that consensus out there among the thinkers, and it is not being readily, or quickly, integrated into the educational system in these areas, STEM areas, across the country, what is the Department of Education doing about that? And why, are they doing it well? Or are they not doing it well? And if they are not doing it well, why not?

Dr. LUFT. Their work is different. I mean, I think——

Mr. MOLLOHAN. The Department of Education?

Dr. LUFT. Well, they have the MSPs and they have the IES grants, the institute grants which develop research, and they are looking for degrees of scale-out in terms of implementation. But when you go into in a separate, so somebody who has worked, you know, remotely with some of those projects and been involved on them, it is not the level, it is, there are different types of projects. I think when you go to NSF you have an investment in curriculum materials, and the development of curriculum materials.

Mr. MOLLOHAN. But I am actually talking about changing the culture. You would think that it is ubiquitous, it sounds like. They would have to go in and really change the——

Dr. LUFT. But they are not. It is not there.

Mr. MOLLOHAN. I mean, some national symposium, or some national study that would redefine how science and math should be taught in education. It seems you would have to deal with it at this level. Because we are down here doing model projects to prove out what has already been proven. Because you have told me, and the last panel told the Committee that inquiry-based education is the way to go. So if that is an established fact among the thinkers then it seems to me the next problem, the real thing that has to happen, is to get it down to it.

Mr. CULBERSON. Mr. Chairman.

Mr. MOLLOHAN. Well, let them answer that, John.

Mr. CULBERSON. Maybe a little help on this?

Mr. MOLLOHAN. Well, let me ask them to help first.

Mr. CULBERSON. Sure.

Mr. MOLLOHAN. And then I will get right to you.

Mr. STRANG. Well, I think this gets back to some of my earlier comments about first of all, sort of a disconnect in priorities. That despite the fact that we know what works in science, science in general is not a priority in our education system.

Mr. MOLLOHAN. Oh my gosh. That shocks me because, and I said this yesterday, that every year the National Science Foundation comes up here and reports on the status of education in America. Science, our students are always behind, as Mr. Schiff and Mr. Fattah pointed out, always behind the world in that. I just have to——

Mr. STRANG. Yes.

Mr. MOLLOHAN [continuing]. At least as it is presented to us through NSF——

Mr. STRANG. Right. So——

Mr. MOLLOHAN [continuing]. It sounds like it is a problem.

Mr. STRANG. Yes. And so, and my earlier comments were that I think that the science agencies, NOAA and NASA and NSF in particular, need to play a lead role in——

Mr. CULBERSON. Bingo.

Mr. STRANG [continuing]. In getting——

Dr. LUFT. Yes.

Mr. STRANG [continuing]. Science education out there in schools. That we cannot expect educators with no background in science to be promoting and implementing and disseminating——

Mr. MOLLOHAN. Ah.

Mr. CULBERSON. That is the key.

Mr. STRANG [continuing]. High quality science education strategies.

Mr. MOLLOHAN. Department of Education?

Mr. CULBERSON. That is what I was going to——

Mr. STRANG. And I think that, you know, I go into elementary schools in California where the school principals are telling their teachers, do not open that science kit until your reading scores are raised.

Dr. LUFT. That is right.

Mr. STRANG. And all the research points to the fact that if they open the science kits, the reading scores would go up. But they are telling their teachers, ubiquitously, across the board, science is not a priority. It is not a priority until your math and your reading scores are up above this line.

Mr. MOLLOHAN. Okay, that is interesting.

Mr. STRANG. Because we get hit over the head if the reading scores are not up. It gets published in the newspaper. 100 percentile, 100 percent science scores do not help us a bit when the scores get published in the newspaper.

Mr. MOLLOHAN. Well, No Child Left Behind ought to hear this. John.

Mr. CULBERSON. Thank you very much, Mr. Chairman. That is the point I wanted to drive home. You are exactly right. That the key is that the National Science Foundation, NOAA, NASA, but particularly NSF need to be the lead on this. And when you get professional educators——

Dr. LUFT. That is right.

Mr. CULBERSON [continuing]. Educrats, as I like to call them, in charge of this they screw it up because they do not understand how important it is. And the root of the problem, Mr. Chairman, I think is, one of many bills that President Bush pursued that I voted against and opposed, in his last, second to last bill, remember Bush pushed a bill that transferred responsibility for science education from the National Science Foundation to the Department of Education.

Dr. LUFT. The MSPs, that was the MSPs.

Mr. STRANG. That was the MSPs.

Mr. CULBERSON. It passed the House. I opposed it. I do not know what happened, I guess it passed in the Senate. Sometimes you lose track of these things. That is the root of the problem. And that is what they are testifying about, is at the Department of Education they are just typical bureaucrats. They do——

Mr. MOLLOHAN. John——

Mr. CULBERSON [continuing]. Not have their priority right.

Mr. MOLLOHAN [continuing]. You do not have to be disparaging.

Mr. CULBERSON. I will be nice. But, I mean, NSF, we need to seriously——

Mr. MOLLOHAN. It is President, President Bush.

Mr. CULBERSON. By President Bush, unfortunately, this is one of many things he did that I voted against. And we need to get it back and NSF needs to be the lead agency. That is the root of the problem.

Mr. MOLLOHAN. Well, that is very interesting.

Mr. FATTAH. Mr. Chairman, this could be a major breakthrough. I think I heard my colleague say that these federal agencies should put together a national science curriculum?

Mr. CULBERSON. No, no, no, be the lead to——

Dr. LUFT. Lead——

Mr. FATTAH. Oh, I am sorry, I did not hear that——

Mr. CULBERSON. With incentives, as I heard the Chairman say. We need to do it through incentives. But NSF clearly needs to be the lead, Mr. Chairman. And whatever we can do to undo making the Department of Education the lead and put NSF back in charge, they would work wonders.

Mr. MOLLOHAN. Okay. Thank you.

Dr. LUFT. It competes with everything.

Mr. CULBERSON. Is that correct?

Dr. LUFT. That is absolutely——

Mr. STRANG. I think there are some studies, some actual cross site analysis of the Math and Science Partnership programs that were run by NSF compared to the Math and Science Partnership programs that were run by the Department of Ed. And across the board, the NSF run programs had stronger outcomes.

Mr. CULBERSON. Yes, that is the root of the problem, Mr. Chairman.

Mr. MOLLOHAN. Did you get that study down? What study is that?

Mr. STRANG. I can send you a citation?

Mr. MOLLOHAN. Please do.

Mr. STRANG. Let me make myself a note.

Mr. FATTAH. Yes, let me just, I am sorry?

Mr. MOLLOHAN. No, Mr. Fattah.

SCIENCE TEACHER CERTIFICATION

Mr. FATTAH. You know, all joking aside, I just want to make sure that the record is clear. I mean, as long as we understand that at this point in time, at the pre-high school in our country, none of the teachers are even subject certified for the most part.

Dr. LUFT. That is right.

Mr. FATTAH. So that in terms of science and all that, in terms of our international competitors they are so far ahead of us by the time our kids show up at high school. And then in many of our both urban and rural areas, and you can go to great, you know, states like my own, you can go to Texas, you can go to West Virginia, there are schools that do not have, they do not have science labs. You know, the Washington Post had a front page story a few years ago, it said that, you know, they focused on one school inside a city, and one school right outside the city, in walking distance literally across the county line. And they described one, and they said one of them had a science lab, and it had, you know, microscopes, and it had, the whole science faculty had advanced degrees in math. And the school had, you know, just, it was a wonderful story.

And then they talked about this other school. And it did not have any working equipment. It had no lab of sorts for kids to do experiment and so on. And nobody had to guess which school was inside the city and which school was in the suburbs. And you did not even have to think about which city, because we know that exists all over our country. And so, you know, we should not be, it is intellectually dishonest for anybody to be surprised when our kids do less well when we test them under these various testing schemes. Because we know that we are giving them less of everything we know they need in terms of learning. So that at the end of the day, you know, that is the challenge that we have. That if we want to do differently we are going to have to act in a much different way. And it will have to be a scale.

And the Chairman is right. We know what works. You know? It is just a question about whether we are going to decide that we are prepared to do to make sure that children are exposed to quality teaching, and, you know, and a rigorous curriculum. Because that will require an investment. And sometimes the tradeoffs between, you know, tax cuts and investing in education politically are more instantaneously rewarding than, you know, it takes a kid, you know, seven years at Penn to get a Ph.D. in math. So if you are starting to worry about this kid in preschool, all the way up to there, you know, it is a thirty-year pipeline.

Mr. CULBERSON. Well, if the gentleman would yield?

Mr. FATTAH. And, you know, we do not have the patience for that in Washington. You know, we do not, it is hard for us to see that far.

Mr. CULBERSON. I really do share, if I could, Mr. Chairman, very briefly, I really want to help you with this. This is, I think, as important to our national security as any investment we make in intercontinental ballistic missiles, or nuclear submarines. Investing in science education, and getting NSF back in the drivers seat I think. I want to help any way I can, Mr. Chairman. I am with you. Thank you.

Mr. MOLLOHAN. No, I welcome that offer for help, particularly from the gentleman. I just want to point out it is going to cost money.

Mr. CULBERSON. No, I am there. Science education, I am there.

Mr. MOLLOHAN. Okay, that is great.

Dr. LUFT. It is the most important thing we can do.

Mr. CULBERSON. As long as there are not national standards.

Mr. FATTAH. Bipartisan——

Dr. LUFT. There are national standards——

Mr. CULBERSON. As long as there is no national curriculum, I should say.

EDUCATIONAL MATERIALS

Mr. MOLLOHAN. Let me, I would like to explore, thank you, thank the gentleman. We will count on it. I would like to explore just a couple of topics here quickly. Materials, we have a lot of materials that are produced by, or do we? Do we have a lot of national textbook material production folks? Or is that pretty well concentrated? And are they embracing inquiry-based education in the curriculum materials that they are producing for school systems?

Mr. STRANG. Well there are many textbook publishers that develop and publish and distribute textbooks. There are really only a handful of instructional materials developers that embody inquiry-based science methods. So that is a smaller subset.

There is the Lawrence Hall of Science and Education Development Center, TERC in Boston, BSCS, there is—you can count them on one or two hands.

Mr. MOLLOHAN. That do inquiry-based materials production. Is it a comprehensive across all the topics you would teach in these areas and for the various grades?

Mr. STRANG. They are—go ahead.

Dr. LUFT. Oh, no, go ahead.

Mr. STRANG. Well they are developers of comprehensive curriculum materials, they are also sometimes the same developers also produce supplemental or enrichment materials or modular materials that can be inserted into other programs. So the range is available, and there are comprehensive materials K through 12, life science, Earth science, physical science that are available for large scale adoptions.

Mr. MOLLOHAN. Yes, doctor.

Dr. LUFT. I concur. I mean, I think that is—there are the materials there, it just becomes—as you get into the secondary level the materials issue becomes a little bit more complex because sometimes you need more advanced materials in order to run the investigations.

So the limiting factor, I mean, you are talking about—you could be talking about microscopes or using advanced equipment. So sometimes just doing some really important investigations are more—require more materials.

Mr. MOLLOHAN. Uh-huh. Well the same, if these—Prentice Hall, that sticks in my mind. Is that a——

Dr. LUFT. That is a publisher.

Mr. STRANG. Textbook publisher, yeah.

Dr. LUFT. Textbook publisher.

Mr. MOLLOHAN. Of academic, yeah. Produce materials and brought them down to a middle school and said we have a whole new set of this inquiry-based and then we have the traditional things you have been buying for years, and gee, you know, we are selling books so we will sell you either group. But that isn't available is it? I mean——

Dr. LUFT. The problem isn't—I mean, I don't want to—the materials are an important piece of this, but the problem is the support that goes on with it. You know if I buy the materials that is fine——

Mr. MOLLOHAN. How do I teach?

Dr. LUFT [continuing]. But how do I really teach using those materials is a key piece, and districts don't have money or they don't have the person who is knowledgeable to support the use of those materials or the teachers.

And we know this too, that teachers can have access to great materials, but they can be used in ways that aren't productive.

Mr. MOLLOHAN. So this has to start back in the education—teacher education.

Dr. LUFT. It has to—you have to hit it all the way through. I mean, you have to always make sure that if you want good science instruction you have really got to make sure that you support it when teachers are in schools, and this is having teachers have access to how to use the materials.

Mr. MOLLOHAN. Yes.

Dr. LUFT. Just buying the materials, anybody is happy to sell the materials, but supporting the materials so the teachers really take that, and studying—it is working with the materials to uncover student's understanding so that we know what to do next.

Mr. MOLLOHAN. Yes.

Dr. LUFT. That is a very powerful piece.

Mr. MOLLOHAN. So it really is a cultural issue. It is all these threads have to be changed in order to——

Dr. LUFT. Yes.

Mr. MOLLOHAN [continuing]. And it has to be coordinated in order to shift.

Dr. LUFT. You are right; in pre-service it is very important that we support these teachers and help them understand how to use the materials. I mean, that is a big piece of it also.

Mr. STRANG. Right. And providing teachers with a consistent message all through their educational career.

Dr. LUFT. Yes.

Mr. STRANG. Including their professional development.

Mr. MOLLOHAN. Yes.

Mr. STRANG. And as a practicing teacher, you know, there should be, I would hope, some unity in the message that they are receiving about these different methods.

The other thing that I just wanted to mention is that when you talked about Prentice Hall saying well we have two sets of materials, the traditional and the inquiry, it is a little bit more complicated than that, because the nature of the development of those materials is very different. And while a textbook publisher can take the most recent set of standards from any particular state and develop a textbook very quickly that addresses everyone of those standards, the development time line for inquiry-based materials might be three years and require a significant investment in the design and development because they are research-based, they are applying educational research and pedagogy, they are extensively pilot tested, field tested, revised and field tested again before they hit the market, and textbook publishers are not typically set up to do that kind of development. That is why we depend on NSF and NOAA and NASA to support the design and development of those materials and then we establish relationships with publishers for the distribution. But without the initial investment from the science agencies the materials would never be developed.

Mr. MOLLOHAN. Thank you for getting that on the record, that is very important to this Committee, because we are interested in supporting that. But it does make the point that materials is development and integration and support for its integration is a real inhibitor to moving in this direction.

Dr. LUFT. But also providing——

Mr. MOLLOHAN. Correct?

Dr. LUFT. Yes.

Mr. STRANG. And the support.

Dr. LUFT. And the support. But I think what would be really great is if NSF did some of this originally was when they developed these materials—and I know that you work with curriculum agencies or with the textbook companies to do the dissemination—but it would be really fantastic if NSF would help develop these materials and also help put them in schools. So if we bypass some of the people who are selling them, but having the people who are developing them really working with teachers to help them put them in schools that would be fantastic. And originally that was done a long, long time ago that was part of the initiative

Mr. MOLLOHAN. Where was that done?

Dr. LUFT. In the—at Sputnik. It was an outgrowth of Sputnik. They actually had the people who were developing the materials were also supporting to put them in schools.

Mr. MOLLOHAN. I guess there is an example out there that we could go look at.

Dr. LUFT. It is a historical example. But now we move through textbook publishers. You may or some do or some don't, but the idea there is this long-term investment even beyond the development of the materials so that it can get into schools and with teachers from the people who had envisioned how they were to be used.

Mr. MOLLOHAN. So who would do the support? I know who would develop the materials, that is the textbook people. If there were a demand out there they would spend the three years developing the materials, but who does the support and where do the resources come? And obviously that would take a lot of re-teaching and re-training. How do you teach this material? So whose responsibility is that?

Mr. STRANG. Well when—I will speak for my institution at the Lawrence Hall of Science. When we develop materials we assume that the development and publication of the materials is the first half of our job.

Mr. MOLLOHAN. Yes.

Mr. STRANG. And we are very deeply involved in the support of the implementation of those materials. So we establish professional networks around the county, centers around the country that are supporting the local implementation of our materials. And the leaders of those centers come to Lawrence Hall of Science and go through days or sometimes weeks worth of professional development with us.

Mr. MOLLOHAN. Is that supported by the marketplace or the educational systems in each state or county, or do you have a grant that is supporting that all the way through?

Mr. STRANG. Our involvement is typically supported by grants, typically NSF.

Mr. MOLLOHAN. Ah.

Mr. STRANG. And——

Mr. MOLLOHAN. So you are—I am sorry to interrupt you. Let me just understand each piece and you remember what you were going to say, if you will.

So you have the grant that helps develop the materials, and also as an academic institution supports the integration of those materials into the classroom——

Mr. STRANG. That is right.

Mr. MOLLOHAN [continuing]. Which really involves teaching the teachers and bringing the teacher back for more education, and then an ongoing—they could pick up the telephone and say gee, I got this problem, you can say——

Mr. STRANG. Right.

Mr. MOLLOHAN [continuing]. This is the solution. That is the kind of system you are talking about.

Mr. STRANG. Absolutely, absolutely. And it happens in a couple of different ways. Probably many more than that, but two that I will mention.

One is that we receive grants to do the development, and then we receive grants to conduct professional development related to the materials that we have developed.

When we are developing the materials, I mentioned a couple of times, we go through this extensive field testing process and we have partnerships with school districts around the country that are very eager to field test our materials because they know that typically they are pretty good, and at the end after the field test they are going to be interested in implementing. And by going through the field test they are building support within their district at the earliest stages for these particular materials.

So teachers that have field tested the materials are very invested in continuing to use them and they get their name in the book as field test teachers and there is some status that goes along with that they work. And we listen to the teachers that are field testing and they can see their comments and feedback reflected in the final drafts.

The other way that that support happens other than the field test and the subsequent grants for professional development, are that in—we chose very carefully the publishers that we establish partnerships with, and the publishers make commitments to school districts that when they purchase the materials there is a certain amount of professional development that will be—that will accompany the purchase of the materials, and then the publishers contract back with us to go deliver the professional development.

Mr. MOLLOHAN. You pay them to do it.

Mr. STRANG. The publishers pay us to do it.

Mr. MOLLOHAN. Oh, oh, okay, I see. I see.

Mr. STRANG. Yes.

Mr. MOLLOHAN. I see. So the grant to develop it and then you have the—they make the commitment and you are subcontracted.

Mr. STRANG. Right.

Mr. MOLLOHAN. Do you have anything to add to that?

Dr. LUFT. I think Lawrence Hall of Science is an exemplary model in how it should work, but in a lot of instances there are districts that don't get that kind of support.

So when I look in the Phoenix metropolitan area there are some schools that I know participate in this, but there are many schools and science teachers that I work with that just don't have access to this. So I don't know.

Mr. MOLLOHAN. Oh, I guarantee you.

Dr. LUFT. Yes. Because this is fiscally intensive, it just doesn't happen. I mean, it is just not that common.

Mr. MOLLOHAN. Well and that is the question, which is what I am saying. How do you scale these proven materials, techniques, how do you scale that up on a national level? So how do you?

Mr. STRANG. Well we went through——

Mr. MOLLOHAN. You have to incentivize somebody.

SYSTEMIC INITIATIVES

Mr. STRANG. Yes. We went through sort of a generation of NSF supported systemic initiatives, statewide systemic initiatives, world systemic initiatives, urban systemic initiatives, et cetera.

Mr. MOLLOHAN. That was about 15 years ago wasn't it?

Mr. STRANG. Yes. And they were across the board; generalizing, pretty successful. And when the funding stopped the fidelity to the implementation started to decrease.

Mr. MOLLOHAN. Yes, but as you point out, the science agencies, you know, simply proving out. They are the ones that understand the science and so you could only expect them to prove it out, they are not going to be sustaining. At some point the state educational systems have to pick this up.

Mr. STRANG. Right.

Mr. MOLLOHAN. They are spending money on science, so obviously it didn't work, because it didn't take.

Mr. STRANG. That is right.

Mr. MOLLOHAN. And why didn't it take to make systemic initiatives? It wasn't mature enough? Your program wasn't mature enough for it to be recognized as the way to go, or it wasn't——

Mr. STRANG. Oh, I think many of those programs used FOSS in the early generations of FOSS, and I think—you know, it is a good question. I don't have a simple answer, but I think that there are a lot of policy issues that impact schools.

So I get back to, you know, we invested all this time and money in purchasing the materials, even in doing professional development, being part of the systemic initiative, and now we are told that the only thing that matters is our reading and math scores.

Mr. MOLLOHAN. So are you suggesting that No Child Left Behind is kind of overtaken with this?

Mr. STRANG. I think there were unintended outcomes to No Child Left Behind——

Mr. MOLLOHAN. Excuse me for interrupting. Are you all telling the authorizing Committee who is reconsidering re-authorization of No Child Left Behind, are you telling them this—these problems?

Dr. LUFT. We are working very hard on doing that on all fronts. I mean we are in academics, we are at the National Science Teacher's Association meeting.

Mr. MOLLOHAN. What about the chairman of the Committee that is dealing with this?

Dr. LUFT. We would be——

Mr. MOLLOHAN. Here.

Dr. LUFT [continuing]. Happy to meet with them and tell them——

Mr. MOLLOHAN. Oh, no, I know you would, I am just wondering if you are.

Dr. LUFT. And you have a lot of teachers in this room who would probably be happy to meet with him and tell him, too.

Mr. MOLLOHAN. Well and the members of Congress that are on that Committee, that is where it all starts. You really have to get in.

PERSONNEL TURN OVER

Dr. LUFT. You are getting at another fundamental issue here that is really problematic too. I mean, we can have the USIs and the rural and urban systemic initiatives were important, but teachers don't stay in the same place the whole time, and neither do administrators, and neither do science specialists. So if you put a lot of resources into help a community develop inquiry, and I was in a district that did, but when the superintendent left, when the science coordinators were done away with, when teachers moved to new schools you have lost the momentum to teach in those settings. So this isn't just something where it is one shot in the arm. You know, you have to kind of keep having boosters in this.

Mr. MOLLOHAN. Well, I mean it would be a bad strategy to embed the ideas in people. You need to embed the ideas in the system.

Mr. LUFT. But the problem is that the system is always fluctuating in education, and that is—we have superintendents who leave if they don't work with the board, we have principals that are moving, you have science coordinators who are—so it is how do we get right the curriculum that is in there and get the sustained professional development for the teachers that they always enact this?

NATIONAL SCIENCE EDUCATION STANDARDS

Mr. MOLLOHAN. Yes.

Mr. STRANG. And I think also when the National Science Education Standards were published in 1996 subsequent to the AAAS benchmarks for science literacy there was a huge emphasis in both of those documents on inquiry-based science education. When the National Science Education Standards were published in 1996, it called inquiry the central strategy of science teaching, and that supported the benchmarks for science literacy that was previously published by AAAS.

So there was wide recognition, and as I think Dr. Luft said, the inquiry was considered content, that this is, you know, this is important for kids to learn, this is as important as any of the concepts.

STUDENT ASSESSMENT

When assessments of student learning were developed most of the assessments focused on assessing student's knowledge of science concepts, because it is easier to assess. So one of the problems is if you are assessing—are we assessing—it is always asking the question, are we assessing the things that we care about, or are we assessing the things that are easy to assess?

Dr. LUFT. Right.

Mr. STRANG. And there is a huge difference and disconnect there that we measure the things that are measurable or cheaply measurable, and that is fine, but we then have to have some way of paying attention to the things we care about that may be more challenging or more expensive to measure. And it is not that it is not possible to measure them, it certainly is possible, but——

Dr. LUFT. It is expensive.

Mr. STRANG [continuing]. It is more complicated and more expensive.

Dr. LUFT. I was actually fortunate to build on this. I was actually fortunate to be in graduate school when they were developing performance assessments that they were going to scale for national assessments, and that is if you really want to get at student understanding, performance assessments are fantastic, but they are difficult because you have to figure out what it is you want to test, but you also have to think about what is the test that you are going to issue. And in science it becomes confounded by the content.

So there was some original work actually done out of California to create some performance assessments that they were looking at that they were doing to disseminate broadly so teachers could do these assessments in class. The beauty behind this assessment is it provided information that was formative so that teachers could know what to do next, but it would also let you know where students were. So it provided more information than just the score on the test, it gave information to a lot of people about how students learned and what teachers could be doing. Those are the rich assessments we need to go after. Those assessments are incredible.

And the reason I think our project kind of came to a halt, they are expensive to enact, they are expensive to calibrate, you have to keep updating them to get people to give them, that is a whole other problem. So it is an expensive business if you want to have a really good assessment that does the right kind of things.

Mr. MOLLOHAN. So is that an ongoing assessment process that it is so expensive and so hard to do, or is that just proving out the system?

Dr. LUFT. That is a great question. It is not that it is—the ongoing process is, say if I am going to give a performance assessment, I am going to have to have somebody give that assessment in multiple classrooms, but then not only that, I have to score these assessments. And these assessments, performance assessments, can be scaled by a rubric, which just states the criteria in where the student is, or it can be, you know, some kind of checklist that you are looking for. But there has to be some accounting of what the student is actually performing or doing, and those—just watching that and gathering that data is very expensive, because it costs people; it is people time.

Mr. MOLLOHAN. Well then that is very sad. Because when you get down into Webster County, West Virginia, which isn't in my district, you get down to Webster County, West Virginia, they are not going to have a lot of money to do that. So if that is true, you can't work around that, and that is—and I am not quite understanding what you are saying, but if that is crucial—I am not quite sure what you are saying with regard to this point. If that is crucial for implementing inquiry-based education then that is very sad, because that will be a real stopper when it gets down to the local level if the school superintendent who has scarce resources has to come up with 2× times how much it costs to test.

Mr. STRANG. Right.

Dr. LUFT. Well, I think the issue is this. If you want science's inquiry the question, and what we are trying to hit on really hard is, that it is how you chose to assess it. And how you chose to assess it is ultimately going to drive how it is enacted.

And you are right, to have the kind of assessments if you want to look to see how a kid is observing, how they are handling this kind of information, the assessments that they develop to do these kinds of things cost a lot of money.

Mr. MOLLOHAN. Is that part and parcel of inquiry—based education for science? A significant increase in the cost of teaching and testing and everything that is involved with it?

Mr. STRANG. So when we develop materials now we build into the instructional materials an assessment system, curriculum embedded assessments that provide teachers with information about student learning for the purpose of informing their own instruction and practice, not for the purpose of grading kids.

Dr. LUFT. Right.

Mr. STRANG. Which is a very different purpose. So when we talk about assessment we need to talk about what is the purpose that this assessment is being used for?

So we build in these curriculum embedded assessments that help teachers to get at student thinking. Where are they in the conceptual development? And we call—there are certain embedded assessment, and then at certain points in the units we have what we call juncture assessments. They are assessments that we want teachers to administer to assess the culmination of students' understanding of a particular concept. And they are junctures because we think if kids haven't generally acquired a certain understanding of the concept the teacher shouldn't go on. They should go back and find opportunities for re-teaching and providing additional experiences. So these juncture assessments are important in the continuity of a unit of instruction.

Part of the problem is that our curriculum embedded assessments do not necessarily provide teachers or school administrators with predictions about how kids will do on their standardized tests at the end of the year. They are completely misaligned.

Mr. MOLLOHAN. We had some testimony here yesterday that there were dramatic improvements. Some people were trying to make the point—and I more understand what they were trying to do—they were trying to make the point gee, inquiry-based, it will result in better test scores on the standardized tests, and that is questioned I guess, but there was some testimony that——

Dr. LUFT. No, it——

Mr. MOLLOHAN. I mean it was just hopeful testimony.

Dr. LUFT. They said yesterday that you could develop instruments that would measure—that would be measurable. That you could develop strong multiple choice.

And I think what you are getting at is where the community is in this. I think there are psychometricians or people who develop tests that say that they can do it, and I think there are people who look at student learning and teacher learning and they say this is a little tougher than that.

Mr. MOLLOHAN. Well, I will tell you, if you are going to move this—just thinking about it as a public policy matter—if you are going to move in this direction then you are going to have to have some sort of work around these two hard of things. Because they can't be too hard to do this or it won't happen.

Mr. STRANG. Agreed.

Mr. MOLLOHAN. So you got to have some work around.

Dr. LUFT. Right, right.

Mr. MOLLOHAN. And it sounds like testing is one of the work arounds.

Dr. LUFT. I think that would be a great place for a lot of work to occur.

Mr. STRANG. Right. And for starters, good assessment, bad assessments aside, or assessments of what we care about and assessments of what we don't care about aside, again, at the elementary level those standardized tests that kids take in fifth grade in science don't really move the needle on the school's academic performance index.

So even if the kids are scoring incredibly high on their science test doesn't really help the school administration.

Dr. LUFT. Right.

Mr. MOLLOHAN. But then it would be understood in this re-authorization I would think.

Mr. STRANG. Yes.

Dr. LUFT. There is one more kind of consequence about this that I just saw for the first time this year that deals with testing, and it is again working in schools which have been very fortunate to do, is that the most important thing we can do is build the capacity of our new teaching workforce. Right?

So this year I was charged with placing teachers in schools. And in one of the schools we wanted to put I know very good inquiry teachers who were doing great things in a science area that is being tested. I said, I would like to put some student teachers in there. And the teacher was very clear with me saying, I can't take the next generation of teachers because I need to make sure that I—these kids, my students hit and do well on that test.

I have never seen this happen before, but we are being locked out now in teacher preparation because of the pressure to achieve on these tests.

Mr. MOLLOHAN. Well, you know, you are telling that to us and we really value that and appreciate your doing that, and as soon as I hear that I think about gee, this person over here better hear that, and that is the person that is fashioning this legislation, and I guess the education—Department of Education who is advising them of what they ought to put into this.

Dr. LUFT. Good teachers don't want to take the risk to build the next generation of teachers.

Mr. MOLLOHAN. Well that is another really difficult problem, I know.

Well, we are drawing to the close of the hearing, and I would like to invite you all here in a summary fashion, and you can talk as long as you want, but in a summary fashion we are an Appropriation Committee, and we are trying to seriously look at this issue. You both have expertise, so as we look at this issue we would like for you to give us advise about how we should be thinking about applying the scarce dollars that we have to have the maximum benefit to achieve the results that we are all—that are implicit here. So, Mr. Strang.

Mr. STRANG. Thank you. Well let me just start by again thanking you and the Committee for inviting both of us here, and it is a pleasure and honor to have the opportunity to share some of this information and hear about your work and some of the challenges that we are all facing together in this endeavor to improve student's abilities to think critically and make their lives better by understanding how the natural world works.

And I guess, you know, one of the things that-this issue of policy constraints is huge, out there in the day-to-day lives of teachers and school principals and school superintendents, and so I think we have talked about that a lot, and I just want to emphasize that no amount of curriculum development or teacher professional development or teacher preparation can really overcome those policy constraints that teachers and schools are under.

The other thing that I want to go back to and reemphasize from my comments is again the importance of the science agencies in leading the effort to improve science education, and there are many reasons for that that we have talked about, and I want to say again that agencies like NOAA and NASA and NSF in addition to having great expertise and understanding of the endeavor of science and how to teach science and how to expose kids to the process of science and scientific habits of mind and scientific ways of thinking, in addition to that they are out there making discoveries every day, and those discoveries need to have a pathway into the curriculum at the earliest levels of a child's educational career. And without the involvement of NOAA and NASA and NSF things like ocean science, like climate change, like atmospheric science, like earth system science will never really get out there to kids. We are still teaching in many school districts early twentieth century science that is divided neatly into biology, chemistry, and physics, and the world of science doesn't work that way anymore.

So NOAA in particular has recently been allowed to play a larger role in science education. Because of their location in the Commerce Department I understand that they had been prohibited from supporting education for many years, and there is some shift in that direction. And with a very small amount of money in a very short time NOAA, combining efforts with NSF has changed my professional world in a way that is hard to explain to you sitting in a Committee room, but ocean sciences education as a community and as a field has advanced a generation's worth in the last five years, and I think there is no underestimating the value that NOAA and NASA and NSF have added to the endeavor of science education.

Mr. MOLLOHAN. Well that is a good endorsement, for we have education accounts in all these, and we want to support them, and that statement is very helpful in justifying our support for it.

Dr. Luft.

Dr. LUFT. I just want to thank you first off for inviting me here today, and it has been great. I work with teachers, I work with teacher educators, I work with principals, I work with superintendents, and I know that at each level everybody would like inquiry implemented.

I also want to say we are, and everybody I have talked to, we are encouraged by this Administration's dedication to science education, and we cannot say thank you enough. It is cool. Science is cool again.

So what I would to say though is NSF has been invaluable in my work, and they have been invaluable to work of a lot of my colleagues. NSF has focused in on transformative work, and that is where they have put the emphasis for a long time, and I think that is very important, but I also think in addition to doing transformative work it is important that you think about what happens to that transformative work.

So it is important that NSF not only be supported for more research and science education, we are just on the cusp of understanding how students learn really complex ideas. We are at the point where we really are starting to understand what is working with, we know what works a lot in PD, but we are getting at some really good novel ideas and we need to kind of keep pushing for that. We need more resources for this kind of work.

NSF needs to be encouraged to continue a research to practice trajectory. They do a lot of great work, and how is it going to make a difference in the lives of teachers? And that is not only science work, but that is work in science education. The new understandings that we have in science education are critical, and we have to have—teachers have to have access to this information.

I think as you heard, it was a great example of the potential of a long-term support program. NSF typically is a PI. We reapply for grants every three to five years. And it would be great, our colleagues, my colleagues in science have long-term funding. They know that their resources are coming year after year for 15 to 20 years, that they can really invest in solving a problem and trying to meet the needs.

I don't know what the answer is for education, but I know it would be nice to know that I can walk in for a lengthy period of time knowing that I can do some development work and get it all out within the same long-term funding cycle. So it would be a little bit novel, but it would be a nice approach.

And I think finally the last piece that I think is important is there has to be just ongoing consistent funding to the science agencies for work in science education. It is difficult to come back with budgets that are reduced or when programs are moved out. The M's piece was a great example. It would be great to make sure that we have a consistent line of funding that is dedicated to this issue.

Again, thank you, and it has been an honor to be here.

Mr. MOLLOHAN. Well it has been an honor to have both of you. When you talk about long-term studies, talk to that a little bit more.

Dr. LUFT. Long-term support is really critical. So I can think of it in a lot of different venues. We are just starting to understand how students learn complex ideas and how these ideas should be sequenced in order to really optimize student learning.

So is there some place where something should be learned before something else, and how do these things build so that students have coherent knowledge? We are just getting into that.

And for those of us who do research around these issues, I need to re-apply every few years. You know, I have to say this is what I am doing. I can't say I am doing more of the same for long. I have to say what is it I am doing that is different sometimes, and that degree of difference has to be really well discussed.

So wouldn't it be great if somebody knew that for ten years I could work to really crack this problem? Or wouldn't it be great if a curriculum developer, as we have heard, knew that he could not only—they could not only develop the curriculum, but they would be responsible for targeting, you know, over 10,000 schools? I mean to have that consistent push would be really powerful. And that puts—that to me is what we are talking about when we are talking about long-term funding.

Mr. MOLLOHAN. So you are suggesting that the original solicitation should provide and make a commitment for resources for a ten-year effort.

Dr. LUFT. For some projects, yes.

Mr. MOLLOHAN. Okay.

Dr. LUFT. I think not all projects merit that, but I think the potential of some of these projects having that kind of—you could be powerful things with that kind of support.

Mr. STRANG. And the support obviously can and should be contingent on demonstrating performance.

Dr. LUFT. Performance.

Mr. STRANG. Yes.

Dr. LUFT. Yes.

Mr. STRANG. So it is not just a contract for ten years regardless, but I think that when warranted——

Dr. LUFT. Yes.

Mr. STRANG [continuing]. That that sort of ongoing funding would make a huge difference.

Mr. MOLLOHAN. Okay. Well finally I would like to invite each of you to submit those and any other recommendations, you know, flesh them out that you would have for the Committee as we consider—as we mark up our bill. So just submit in writing what you have said just now here at the summary——

Dr. LUFT. Yes.

Mr. MOLLOHAN [continuing]. And what would you like to see.

Dr. LUFT. It is a big decision.

Mr. MOLLOHAN. I am not saying that we can do it——

Dr. LUFT. Okay.

Mr. MOLLOHAN [continuing]. I am just saying we would like to see if. There is no commitment.

Thank you all very much for your appearance here today.

Dr. LUFT. No, thank you.

Mr. STRANG. Thank you very much.

Mr. MOLLOHAN. We very much appreciate it. Thank you.

Mr. STRANG. Thanks.

Dr. LUFT. Thanks.

WEDNESDAY, FEBRUARY 24, 2010.

FISCAL YEAR 2011 BUDGET FOR SCIENCE AND TECHNOLOGY

WITNESS

DR. JOHN P. HOLDREN, PRESIDENT'S SCIENCE ADVISOR

OPENING STATEMENT—CHAIRMAN

Mr. MOLLOHAN. The hearing will come to order. Good afternoon. Welcome, doctor. Welcome everybody to the hearing of the Subcommittee on Commerce, Justice, and Science for fiscal year 2011. Today we will cover the budget status and future prospects of U.S. research and development. Our witness is the President's Science Advisor and Director of the Office of Science and Technology Policy, Dr. John P. Holdren. Dr. Holdren, this is your first appearance before this Subcommittee, and we have much to discuss. And we would like to especially welcome you to the job and to the hearing.

Based on considerable evidence, real growth in the United States economy, in excess of population growth, is primarily the result of the innovations and new technologies that result from public and private investments in research and development. Accordingly, we are in the midst of a ten-year doubling in funding for NSF, NIST, and the Department of Energy Office of Science as contemplated by the America Competes Act. This doubling was accelerated by $18.5 billion added to the fiscal year 2009 appropriation for R and D in many agencies as part of the American Recovery and Reinvestment Act. Those funds have gone to increase grant funding across all areas of science and to various science infrastructure investments.

Within the Subcommittee's purview the budget request for fiscal year 2011 continues the planned doubling for NSF and NIST with roughly 7 percent increases over the 2010 enacted levels. While this doubling was authorized in the America Competes Act, that authorization was only through fiscal year 2010. The budget strengthens climate observing and research through significant increases for NOAA R and D, including equipment and development for polar orbiting satellites, and NASA Earth science missions and research. While funding for planetary research has increased, funding for other areas of NASA science is essentially frozen. While our climate related activities are a higher priority, all of NASA's science contributes to the nation's science enterprise just as much as does funding for NSF, NIST, and the DOE Office of Science.

In fiscal year 2010 this Subcommittee supported an increase to NSF education programs focused on hands-on, inquiry-based instruction in grades K–12 and in K–12 teacher preparation. Earlier this year, in hearings which we held, we heard testimony from those who work in this area. They provided examples of successful efforts in improving science, technology, engineering, and math education, STEM education, evidence of the benefits that result from federal investments made through NSF, NOAA, and NASA. For decades the science and education communities have stated that inquiry is essential to effective STEM education. And yet, it remains rare in K–12 and college teaching. It is high time to change this.

Given the critical role of science and technology in the future prosperity and international leadership of the United States, we look forward to hearing from Dr. Holdren on the state of U.S. science and technology, its position relative to other countries, and its future needs and prospects.

Dr. Holdren, before I ask you to summarize your remarks, and your written statement will be made a part of the record, I would like to call on Mr. Culberson for any comment he should like to make.

Mr. CULBERSON. Thank you very much, Mr. Chairman. On behalf of Ranking Member Wolf, Frank would like to present his statement in person. So I want to reserve the right to allow Mr. Wolf to make his opening statement in person. He will be here very shortly. He is at a funeral at Arlington.

Mr. MOLLOHAN. Certainly.

Mr. CULBERSON. Thank you, Mr. Chairman.

Mr. MOLLOHAN. You are welcome. Dr. Holdren.

OPENING STATEMENT—WITNESS

Dr. HOLDREN. Thank you, Mr. Chairman and members of the Committee. It is really a privilege to be here today to talk about the research and development and the STEM education components of the President's fiscal year 2011 budget. As you noted, Mr. Chairman, I submitted a written statement as well.

The administration is working hard to keep the nation on the path out of recession through recovery and into a new era of revitalized growth. That of course means sparking job creation to get millions of Americans back to work. It means building a new foundation for a long term prosperity that will reach every American family. And a crucial element of that effort is the targeted investments that we are making in science, technology, and innovation that will lead to new products and services, new businesses and industries, increased American competitiveness, and high quality sustainable jobs. Our strategy includes investments in fundamental and applied research and development that will lead to better technologies and the jobs that will go with them for advanced manufacturing, for clean energy, for healthcare, for environmental protection and remediation, and for national and homeland security. And it includes increased use of public-private partnerships to speed up innovation and get the results more rapidly into the marketplace. It calls for exploration and discovery from the depths of the oceans to the frontiers of space, expanding our knowledge of our world and our universe while igniting the curiosity and ambitions of our young people. And it includes a focus on STEM education that will support and sustain, rather than stifle, that curiosity so that we can cultivate the next generation of innovators along with the technology savvy workforce that competitiveness in the 21st century requires.

Obviously we need the continuing support of the Congress, and importantly the continuing support of this Committee, to get it done. But if there is one message I most want to convey in my comments today it is that the investments in the President's R and D budget are at the very core of America's future strength. So I am certainly looking forward to working with all of you to make sure at this very important time in our history, when competition abroad is growing and the stakes are ever increasing, that we put America on a path that keeps this nation great for our children and grandchildren. A path that is built on scientific evidence, on technical progress and prowess, and on a nation of people who are inventors, innovators, and makers, not just consumers.

Let me give you a very brief bird's eye view of the fiscal year 2011 R and D budget, and then elaborate on a few highlights. The President's 2011 budget proposes a record $61.6 billion of investment in civilian research and development, not including facilities and equipment. That is an increase of $3.7 billion or 6.4 percent over the 2010 funding level. Those increases are counterbalanced by some reductions in defense development funding, such that the combined defense and non-defense R and D budget would be $147.7 billion. That is just two-tenths of a percent above the enacted 2010 level. If you adjusted for projected inflation it would be a cut of about nine-tenths of a percent. I think this is a smart R and D budget, one that is fiscally responsible overall with some important targeted increases where investments today can do the most good for us tomorrow.

Among the highlights let me first note, as you did Mr. Chairman, that the 2011 budget reflects the President's commitment to double the budgets of the National Science Foundation, the DOE's Office of Science, and the NIST laboratories. The President's plan for science and innovation, and the America Competes Act, as you noted, identified those three agencies as key to the fundamental research that underpins our future prosperity. And fundamental research which the private sector will never do enough of because the risks seem too high and the returns seem too far in the future. Last year this Congress and this administration worked together to put those agencies back on a doubling trajectory that had faltered in the previous administration, and the fiscal year 2011 maintains that trajectory with a 6.6 percent increase for their combined budgets.

I want to highlight as well some of our goals within the National Oceanic and Atmospheric Administration, NOAA, which plays a vital role in supporting research on the earth's oceans, atmosphere, and marine habitats. The NOAA budget of $5.6 billion is an increase of $806 million over the 2010 enacted level. That is going to allow NOAA to improve weather and climate services that protect life and property, invest more heavily in restoring our oceans and coasts, and to ensure continuity of satellite observations of weather and climate that are crucial.

I want to emphasize some recent progress in that latter area. The large increase in the NOAA budget reflects in part a new architecture for the National Polar Orbiting Operational Environmental Satellite System, NPOESS, which is a tri-agency program, NOAA, DOD and NASA, that has had a troubled history. Since last

August OSTP has led an Executive Office of the President task force that, in close cooperation with those three partner agencies, has been investigating various options for how to place the NPOESS program on a pathway to succeed. Earlier this month the three agencies announced a plan to restructure the program—a plan reflected in the 2011 budget. And under this plan there will be a division of satellite acquisition but the three agencies will continue to partner in areas that they have successfully shared in the past, including the ground systems and the data management. I want to assure the Committee that OSTP will continue to be engaged in overseeing the transition to the new structure of this critical program.

A number of other items in the R and D budget, I think, are worth highlighting, including support for activities in the next generation air transportation system, NextGen; the added billion dollars in the National Institutes of Health to speed discovery of new treatments and cures for cancer and other diseases; the added support for the Defense Advanced Research Projects Agency, DARPA, for research in high priority areas such as night vision, cybersecurity, enhanced GPS, and force protection; the more than 25 percent increase in funding for environmental health and safety studies under the National Nanotechnology Initiative; and the significant increase in support for the multiagency U.S. Global Change Research Program mandated by Congress to improve understanding of climate science, expand global observing systems, and develop science-based resources to support policy making and resource management.

I want to focus on two other areas before my time is up. The first of those is NASA. Our space program in the United States represents not just a grand and inspiring adventure of exploration and discovery reaching outward into our universe, but it is also an indispensable platform for observing what is happening on the Earth below. It is a crucial element of our communications infrastructure and our geopositioning capability. It is a source of new products, services, businesses, and jobs whose potential is barely beginning to be tapped. The fiscal year 2011 NASA budget proposes a science and technology centered restructuring of this country's space exploration program. It will invest in American ingenuity to enable us to do things in space that are more useful, more exciting, and more affordable then returning astronauts to the moon surface fifty years after we did it the first time using essentially the last century's technology.

The new approach, which adds $6 billion over the next five years for NASA, includes a vigorous technology development and test program that will begin to reverse decades of underinvestment in NASA in new ideas. It will extend the life of the International Space Station, likely to 2020 or beyond, thereby increasing the number of U.S. astronauts who will be working in space over the next decade. It will support the development of private sector capabilities to lift astronauts into low Earth orbit and it will shorten the duration of our reliance solely on Russian launchers for that purpose. And by investing in new game changing technologies it gives promise of getting our astronauts to deep space destinations sooner, faster, safer, and cheaper than what could realistically have been achieved under the old approach.

Finally just a few words about STEM education, which you also, Mr. Chairman, mentioned in your opening remarks. The President has been emphatic about his commitment, which I share, to increase the participation and the performance of American students in science, engineering, mathematics, and technology, aiming to improve our performance in comparison with other nations from the middle of the pack to the top of the pack over the next decade. The 2011 budget would invest $3.7 billion in STEM education programs across the federal government, including a $1 billion investment in improving math and science education among K–12 students. That is an increase of over 40 percent in that category. The impact of those investments is going to be magnified by the Educate to Innovate Campaign launched by the President late last year to motivate and inspire young people to excel in STEM fields. This campaign has already mobilized over $500 million in financial and in-kind support from companies, foundations, universities, and nonprofits. In addition to those investments the 2011 budget provides an additional $1.35 billion in funding for Race to the Top, a Department of Education program which provides a competitive advantage to states that commit to a comprehensive strategy to improve STEM education.

The investments in R and D and in STEM education proposed in the President's fiscal year 2011 budget reflect his clear understanding of the importance, the critical importance, of science, technology, and innovation in addressing the most compelling challenges our nation faces while respecting, at the same time, the need for overall budgetary restraint under difficult economic conditions. It is a budget intended to keep this country on a path to revitalized economic growth, real energy security, intelligent environmental stewardship, better health outcomes for more Americans at lower costs, strengthened national and homeland security, and continuing leadership in science and in space. I look forward to working with this Committee to make the vision of the President's fiscal year 2011 budget proposal into a reality, and of course I will be pleased to try to answer any questions the members may have.

Statement of Dr. John P. Holdren
Director, Office of Science and Technology Policy
Executive Office of the President of the United States
to the
Committee on Appropriations
Subcommittee on Commerce, Justice, Science, and Related Agencies
United States House of Representatives
on
Research and Development in the President's Fiscal Year 2011 Budget
February 24, 2010

Chairman Mollohan, Ranking Member Wolf, and Members of the Committee, It is my distinct privilege to be here with you today to discuss the R&D and STEM-education components of the President's FY2011 Budget.

Administration Initiatives in Science, Technology, and Innovation

The Obama Administration is working hard to keep the Nation on the path out of recession through recovery and into a new era of revitalized growth. This means sparking job creation to get millions of Americans back to work, and it means building a new foundation for long-term prosperity that will reach every American family. A crucial element of this effort is the targeted investments we're making in science, technology, and innovation (STI) that will lead to new products and services, new businesses and industries, and high-quality, sustainable jobs.

Our STI strategy includes investments in applied research and development that will lead to better technologies – and the jobs that will go with them – for advanced manufacturing, for clean energy, for health care, for environmental protection and remediation, and for national and homeland security. It includes increased use of public-private partnerships to speed up innovation and get the results more rapidly into the marketplace. And it includes investments in the foundations of national strength in STI:

- fundamental research and the facilities and equipment needed to do it;
- domains of exploration and discovery from the depths of the oceans to the frontiers of space, expanding our knowledge of our world and our universe while igniting the curiosity and ambitions of our young people; and
- science, technology, engineering, and math (STEM) education that will build on rather than stifle that curiosity and will enable those ambitions, giving us a bigger and better-prepared next generation of innovators, along with the tech-savvy workforce that competitiveness in the 21st century requires.

Because President Obama understands the crucial connections linking STI and STEM education to our ability to meet the great challenges before us, his 2011 Budget provides strong and strategic investments in these domains despite the overall budget austerity that the country's fiscal circumstances require. At a difficult time in the nation's history, the President's 2011 Budget proposes to invest in science, technology, and innovation today to meet the challenges of tomorrow. Obviously, we need the continued support of the Congress to get it done. In the remainder of this testimony, I elaborate on the reasons the President and I are most hopeful you'll provide that support.

The Federal R&D Budget

The President's 2011 Budget proposes a record $61.6 billion investment in civilian research and development, an increase of $3.7 billion or 6.4 percent over the 2010 funding level, reflecting the Administration's firm belief that investment in innovation is the key to building the American economy of the future. This Budget builds on the 2009 and 2010 appropriations approved by Congress, and if passed as proposed would mark the third year in a row of real increases for Federal nondefense R&D and Federal research, following four years of real decline between 2004 and 2008.

These important R&D investments aim to bolster the fundamental understanding of matter, energy, and biology that are at the root of all innovation and to foster significantly new and potentially transformative technologies. While reducing some development funding and scaling back on R&D facilities and equipment, all told, the total (defense and nondefense) R&D budget would be $147.7 billion, just $343 million or 0.2 percent above the 2010 enacted level, or a 0.9 percent cut after adjusting for projected inflation.

Science is also fundamental to ensuring that Americans are safe and secure. That is why the Defense Department budget also devotes $2 billion to basic research, considerably higher than in 2010, while reducing the Department's overall R&D budget by some $3.5 billion—a reduction in spending achieved in large part by cutting lower-priority weapons-development programs.

Budgets of Science Agencies

The 2011 Budget also reflects the President's commitment to double the budgets of the National Science Foundation, a primary source of funding for basic academic research; the DOE's Office of Science, which leads fundamental research for energy and builds and operates accelerators, colliders, supercomputers, and facilities for making nano-materials; and the National Institute of Standards and Technology laboratories, which support a wide range of pursuits from accelerating standards development for health information technology and "smart grid" technologies to conducting measurement science research to enable net-zero energy buildings and advanced manufacturing processes.

The President's Plan for Science and Innovation and the America COMPETES Act have identified these three agencies as key to our nation's future prosperity and to preserving America's place as the world leader in science and technology. Although the previous Administration supported an effort to double these agencies' budgets between 2006 and 2016, these efforts fell short in 2007 and 2008. But last year, this Congress and this Administration worked together to finally put these agencies on a doubling trajectory, and the FY2011 budget maintains that trajectory with a 6.6 percent increase for their combined budgets, totaling $13.3 billion.

I now turn to the budgets of individual agencies under this subcommittee's jurisdiction in a bit more detail.

National Science Foundation (NSF)

The National Science Foundation (NSF) is the primary source of support for academic research for most non-biomedical disciplines, funding basic research across the entire spectrum of the sciences and engineering. It is well regarded for funding nearly all of its research through a competitive, peer-reviewed process. The 2011 Budget requests $7.4 billion for NSF, an increase of 6.9 percent in real terms above the 2010 funding level (8.0 percent in current dollars). This keeps NSF on track to double its budget as promised in the President's Plan for Science and Innovation. In addition, last year the Recovery Act provided $3.0 billion for NSF.

Basic research funding is important not only because it leads to new knowledge and new applications but also because it trains the researchers and the technical workforce of the future. In recognition of this dual benefit to society and of NSF's special contribution, the 2011 Budget continues the President's commitment to triple the number of new NSF Graduate Research Fellowships to 3,000 a year by 2013. The 2011 Budget also requests $64 million for the Advanced Technological Education (ATE) program to promote partnerships between higher-education institutions and employers to educate technicians for the high-technology fields that drive our nation's economy.

NSF also proposes to increase research funding to promote discoveries that can guide societal actions leading to environmental and economic sustainability. The Science, Engineering, and Education for Sustainability portfolio will increase to $766 million in the 2011 Budget for integrated activities involving climate, environment, and energy. NSF is also committed to enhancing U.S. economic competitiveness with Science and Engineering Beyond Moore's law, a multidisciplinary research program designed to meet some of today's most daunting computational challenges.

NSF will also be collaborating with the Department of Energy (DOE) on the RE-ENERGYSE (Regaining our ENERGY Science and Engineering Edge) program to attract and educate future American scientists in the clean energy field. NSF's proposed contribution is $19 million and DOE's is $55 million in 2011.

National Aeronautics and Space Administration (NASA)

Our U.S. space program represents not just a grand and inspiring adventure of exploration and discovery looking outward at our universe, but also an indispensable platform for observing what is happening on the Earth below, a crucial element of our communications infrastructure and geopositioning capability; and a source of new products, services, businesses, and jobs whose potential is barely beginning to be tapped.

The FY2011 NASA budget launches a bold new space initiative that invests in American ingenuity to enable us to do things in space that are more useful, more affordable, and more exciting than returning astronauts to the Moon's surface 50 years after we did it the first time, using the last century's technology. The new approach – which adds $6 billion over the next five years for NASA – includes a vigorous technology development and test program that will begin to reverse decades of under-investment in new ideas. By extending the life of the International Space Station, it increases the number of U.S. astronauts who will be working in space over the next decade; by supporting the development of private-sector capabilities to lift astronauts into low Earth orbit it will shorten the duration of our reliance solely on Russian launchers for this purpose; and by investing in new, game-changing technologies it gives promise of getting our astronauts to deep space destinations sooner, faster, safer, and cheaper than what could realistically have been achieved under the old approach.

Let me provide some budget detail. The President's Budget supports the extension and enhanced utilization of the Space Station with a full complement of international crew and laboratories: it provides $2.8 billion in 2011, $463 million more than in 2010, to extend operations of the Space Station past its previously planned retirement of 2016, likely to 2020 or beyond. It funds a technology-demonstration program at $7.8 billion over 5 years to support the development and demonstration of technologies to reduce the cost and expand the capabilities of future exploration activities, including in-orbit refueling and storage. There will be $3.1 billion over 5 years for heavy-lift and propulsion R&D on new launch systems, propellants, materials, and combustion processes. And the Budget anticipates an investment of $3.0 billion over 5 years to fund robotic precursor missions to scout exploration targets.

The Budget proposes $5.0 billion in 2011 for the NASA's Science portfolio, an increase of more than $500 million compared to 2010. This increase allows for numerous exciting scientific opportunities in space: re-flying the Orbiting Carbon Observatory (OCO), which is crucial to our understanding of the Earth's carbon cycle and its effect on climate change; accelerating the development of other satellites to enhance observations of the climate and other Earth systems; and continuing to increase our understanding of the cosmos through such projects as the follow-on to the Hubble Space Telescope.

Department of Commerce National Institute of Standards and Technology (NIST)

The National Institute of Standards and Technology (NIST) laboratories advance technological innovation through advanced measurement science research and standards development. The 2011 Budget of $709 million for NIST's intramural laboratories, a 6.9 percent increase over the 2010 enacted level, will improve NIST's research capabilities by providing high-performance laboratory research and facilities for a diverse portfolio of research in areas such as advanced manufacturing, health information technology, cybersecurity, interoperable smart grid, and advanced solar energy technology. For NIST's extramural programs, the 2011 Budget requests $130 million for the Hollings Manufacturing Extension Partnership (MEP), a $5 million increase over the 2010 enacted level. The 2011 Budget also requests $80 million for the Technology Innovation Program (TIP), a $10 million increase over 2010. All of these NIST programs are important components of *A Framework for American Manufacturing*, a comprehensive strategy for supporting American manufacturers announced in December.

Department of Commerce National Oceanic and Atmospheric Administration (NOAA)

The National Oceanic and Atmospheric Administration (NOAA) plays a vital role in research on the Earth's oceans, atmosphere, and marine habitats. The NOAA budget of $5.6 billion is an increase of $806 million over the 2010 enacted level. This will allow NOAA to strengthen the scientific basis for environmental decision-making, improve weather and climate services that protect life and property, invest more heavily in restoring our oceans and coasts, and ensure satellite continuity.

NOAA satellite systems, which are essential to our understanding of weather and climate, are a top priority in the 2011 Budget. The large increase in the NOAA budget reflects a new architecture for the National Polar-orbiting Operational Environmental Satellite System (NPOESS). This tri-agency (NOAA, DOD Air Force, and NASA) program has had a long and troubled history. Since last August, OSTP has led an Executive Office of the President Task Force that, in close cooperation with the partner agencies, has been investigating various options for how to place the NPOESS program on a pathway to success. Last week, the three agencies announced a plan to restructure the program – a plan reflected in the President's 2011 Budget. NOAA and the Air Force will no longer jointly procure NPOESS; rather, NOAA and NASA will take primary responsibility for procuring satellites for the afternoon orbit and DOD will take primary responsibility for the morning orbit. The three agencies will continue to partner in areas that have been successfully shared in the past, such as the program's ground system. Although NOAA's 2011 Budget proposes a substantial increase to support NOAA's expanded NPOESS responsibilities under the restructuring, we intend to make full use of the NPOESS investments and work done to date by all the NPOESS parties. I can assure the committee that OSTP remains actively engaged in overseeing the transition to a new direction for this program and committed to ensuring continuity of satellite coverage needed for weather forecasting and storm tracking, as well as for climate data records.

White House Office of Science and Technology Policy (OSTP)

The White House Office of Science and Technology Policy (OSTP) works with OMB to ensure that the President's S&T priorities are reflected in the budgets of all of the Executive Branch departments and agencies with S&T and STEM-education missions. OSTP also provides science and technology advice and analysis in support of the activities of the other offices in the Executive Office of the President and supports me in my role as the Assistant to the President for Science and Technology, with the responsibility to provide the President with such information about science and technology issues as he may request in connection with the policy matters before him. In addition, OSTP coordinates interagency research initiatives through administration of the National Science and Technology Council (NSTC), serves as the lead White House office in a range of bilateral and multilateral S&T activities internationally, and provides administrative and technical support for the very active 21-member President's Council of Advisers on Science and Technology (PCAST).

OSTP personnel in addition to the Director include a Senate-confirmed Associate Director for Technology, who is also the Nation's Chief Technology Officer; three further Senate-confirmed Associate Directors (for Science, Environment, and National Security and International Affairs): and a further 40 technical professionals plus supporting administrative staff. The 2011 Budget requests $6.990 million for OSTP's operations, slightly below the 2010 enacted funding level. This support for OSTP reflects the President's continuing recognition of the importance and diversity of OSTP's functions in keeping "science in its rightful place" in his Administration, as he pledged in his Inaugural Address.

Interagency Initiatives

A number of priority interagency S&T initiatives are highlighted in the President's 2011 Budget. These initiatives are coordinated through the NSTC, which as noted above is administered by OSTP.

Networking and Information Technology R&D

The multi-agency Networking and Information Technology Research and Development (NITRD) Program plans and coordinates agency research efforts in cyber security, high-end computing systems, advanced networking, software development, high-confidence systems, information management, and other information technologies. The 2011 Budget provides $4.3 billion for NITRD.

Networking and computing capabilities are more critical than ever for national and homeland security, reforming the health care system, understanding and responding to environmental stresses, increasing energy efficiencies and developing renewable energy sources, strengthening the security of our critical infrastructures including cyberspace, and revitalizing our educational system for the jobs of tomorrow. The 2011 Budget retains an important focus on investment in high-end computing research for both national security and large-scale scientific applications, particularly in advanced scalable simulations. The 2011 Budget also continues to emphasize foundations for assured computing and secure hardware, software, and network design and engineering to address the goal of making Internet communications more secure and reliable.

National Nanotechnology Initiative

The 2011 Budget provides $1.8 billion for the multi-agency National Nanotechnology Initiative (NNI), a reduction of $19.5 million from the enacted 2010 level. Research and Development in the NNI focuses on the development of materials, devices, and systems that exploit the fundamentally distinct properties of matter at the nanoscale. NNI-supported R&D is enabling breakthroughs in biomedical detection and treatment, manufacturing at or near the nanoscale, environmental monitoring and protection, energy conversion and storage, and novel electronic devices, among many others. The 2011 Budget proposes $35 million for nano educational and societal dimensions research and $101 million across several agencies for nanomanufacturing.

Consistent with the NNI Strategy for Nanotechnology-Related Environmental Health and Safety (EHS) Research, agencies maintain a focus on developing nanotechnology responsibly, with attention to the human health and environmental impacts as well as ethical, legal, and other societal issues. In recognition of the special importance of these issues, the 2011 Budget increases the priority of nano EHS research with a request of $117 million, more than 27 percent above the 2010 level.

U.S. Global Change Research Program

The Budget includes an expanded commitment to global change research. Investments in climate science over the past several decades have contributed to an improved understanding of global climate. These additional investments will be a critical part of the President's overall strategy to mitigate U.S. greenhouse gas emissions and move toward a clean energy economy. To continue to assist the government and society to understand, predict, project, mitigate, and adapt to climate change, the 2011 Budget provides $2.6 billion for the multi-agency U.S. Global Change Research Program (USGCRP), an increase of 21 percent or $439 million over the 2010 enacted level.

The USGCRP was mandated by Congress in the Global Change Research Act of 1990 (P.L. 101-606) to improve understanding of uncertainties in climate science, expand global observing systems, develop science-based resources to support policymaking and resource management, and communicate findings broadly among scientific and stakeholder communities. Thirteen departments and agencies participate in the USGCRP. OSTP and the Office of Management and Budget (OMB) work closely with the USGCRP to establish research priorities and funding plans to ensure the program is aligned with the Administration's priorities and reflects agency planning.

In addition to enhancing research and modeling of the physical climate system, the 2011 USGCRP Budget will also allow for a comprehensive, coordinated focus on four areas of particular need: Earth observations, adaptation research, integrated assessment, and climate services.

Innovation, Entrepreneurship, and Job Creation

The President believes that we must harness the power and potential of technology, data, and innovation to transform the nation's economy and to improve the lives of all Americans. The President's 2011 Budget targets strategic investments in technology to spur innovation in the public and private sectors and does so in a manner that changes the way Washington works. Let me share with you a few key highlights.

As articulated in the President's *Strategy for Innovation* released last year, the Budget proposes a permanent extension of the research and experimentation (R&E) tax credit to spur private investment in research and development (R&D) by providing certainty that the credit will be available for the duration of the R&D investment.

The Budget also promotes the commercialization of promising technologies through smart, strategic investments. The Budget proposes $12 million for the National Science Foundation (NSF) to support a new Innovation Ecosystem where universities will partner with other institutions to increase the impact of the most promising innovations through commercialization, industry alliances, and start-up formation. The Budget proposes an additional $10 million in National Institute of Standards and Technology (NIST) programs to foster innovation in manufacturing with an emphasis on sustainable nanomanufacturing.

The Administration also recognizes that competitive, high-performing regional economies are the building blocks of national growth, and that we must expand and accelerate our efforts to cultivate regional economic clusters across the country. The Budget provides at least $75 million in regional planning and matching grants within the Economic Development Administration (EDA) to support the creation of regional innovation clusters that leverage regions' competitive strengths to boost job creation and economic growth.

What I have given you is only a brief snapshot. As you know, there is important work being done in broadband, spectrum policy, patent reform, standards and measurements for emerging technologies, support for the development and adoption of health information technology, and export promotion. These efforts and investments will help build the foundation for sustainable recovery, by fostering the new jobs and industries that will arise from the innovative and entrepreneurial talents of the American people.

Science, Technology, Engineering, and Mathematics (STEM) Education

The President has been emphatic about his commitment, which I share, to increase the participation and the performance of American students in science, technology, engineering, and mathematics, aiming to improve our performance in comparison with other nations from the middle of the pack to the top of the pack over the next decade. Over the past year, OSTP has been working with the White House Domestic Policy Council, the Department of Education, and a number of science and technology agencies to identify and promote concrete actions to help meet this ambitious goal.

The 2011 Budget invests $3.7 billion in STEM education programs across the federal government, including a historic $1 billion commitment to improve math and science achievement among K-12 students, that latter figure an increase of over 40 percent. The impact of these investments will be magnified by "Educate to Innovate", a campaign launched by the President to motivate and inspire young people to excel in STEM education. This campaign has already mobilized over $500 million in financial and in-kind support from companies, foundations, philanthropists, universities, non-profit organizations, and grassroots volunteers.

In addition to these investments, the Administration has made great strides in integrating STEM education into broader education programs. For example, the $4.35 billion Race to the Top fund in the Recovery Act provides a competitive advantage to states that commit to a comprehensive strategy to improve STEM education. The 2011 Budget, by providing an additional $1.35 billion in funding for Race to the Top, builds on these historic investments to create state capacity, focus on student achievement, and help prepare America's students to graduate ready for college and careers.

This Administration is committed to investing in and scaling what works, and to improving the coordination of federal STEM education programs. The Department of Education and the National Science Foundation (NSF) are leading an effort, with active OSTP participation, to increase the impact of the Federal STEM investments I've outlined above by (1) developing an aligned strategy that emphasizes key agency capacities; (2) clarifying evidence standards used to assess program impact; and (3) identifying the most promising STEM efforts for further validation, testing, and suitability for scale-up. OSTP looks forward to working with this Committee on our common vision of improving STEM education for all of America's students.

Conclusion

The investments in R&D and STEM education proposed in the President's FY2011 Budget reflect his clear understanding of the critical importance of science, technology, and innovation in addressing the most compelling changes our Nation faces. While respecting the need for overall budgetary restraint under difficult economic conditions, the President is recommending an array of investments in R&D and STEM education that will keep this country on a path to revitalized economic growth, real energy security, intelligent environmental stewardship, better health outcomes for more Americans at lower costs, strengthened national and homeland security, and continuing leadership in science and in space. I look forward to working with this Committee to make the vision of the President's FY 2011 Budget proposal into a reality. I will be pleased to try to answer any questions the Members may have.

Mr. MOLLOHAN. Dr. Holdren, Mr. Wolf has arrived and I am going to let him make his opening statement. Then I will pick up with my questioning, and then I will yield to Mr. Wolf to follow with his questioning. And then we will proceed in the order of members' arrival here today. After which I will be turning the chair over to one of the ranking members because the EPA administrator is before the Interior Committee and I need to appear there.

Mr. Wolf, I yield to you for your opening statement.

OPENING STATEMENT—RANKING MEMBER

Mr. WOLF. Thank you, Mr. Chairman. And I apologize for not being here. I was at a funeral at Arlington Cemetery and I just got back, so I do apologize.

I just want to make this clear because of your important position. Last October the Augustine Commission issued a report entitled, "Seeking a Human Space Flight Program Worthy of a Great Nation." The proposal this administration has submitted for NASA to abandon the Constellation vision and strategy leaves the program worthy of a lesser nation than the United States. You are proposing the most radical change to NASA's mission and program since its inception, and yet the President has been silent, and the White House has been silent since the release of the budget.

You may recall that in August 2008, then candidate Obama told an audience of 1,300 people in Florida, "Here is what I am committing to: to continue Constellation." This is a notable reversal from the President that will have a devastating, I believe, impact, the consequences for decades for the future, for the future of young people, for the future of this country.

Based on the little information that was provided to the Congress, it appears that this plan was hastily developed without proper vetting from NASA's scientific and human space flight experts. Over the last week I have heard from a number of Apollo astronauts and NASA leaders. I would like to share with the Committee, and with you, just a few of the initial reactions and submit their full statements for the record.

Former NASA Administrator Dr. Mike Griffin wrote, "I believe this budget request advocates a strategy that is frankly disastrous for the U.S. human space flight program." He added that this proposal clears the way for the Chinese dominance in space. China, which has thirty-four Catholic bishops in jail, hundreds of Protestant pastors, spies against us every day, will literally take the lead with regard to this program.

Dr. Chris Kraft, the legendary Apollo flight director and former Johnson Space Center Director said, "The U.S. space program is in great peril if the President's budget proposals are enacted."

Apollo 7 astronaut Walter Cunningham wrote, "This budget proposal," he said, "accelerates America's downward spiral toward mediocrity in space exploration."

Apollo 17 astronaut and former U.S. Senator Harrison Schmitt wrote that this proposal would "cede the moon to China, the American space station to Russia, and consign liberty to the ages. Other nations would accrue the benefits—psychological, political, economical, and scientific—that the United States harvested as a consequence of Apollo's success forty years ago. This lesson had not been lost on our ideological and economic competitors."

Apollo 16 astronaut Charlie Duke said, "We cannot afford to lose our leadership in space. The Constellation program must be continued."

And perhaps most notably, I received a letter from Burt Rutan, the X prize winner who flew the first private commercial craft into space in 2004, who ardently opposes this budget proposal. He said, "An observer might think that I would applaud a decision to turn this important responsibility over to commercial developers. However," he said, "he would be wrong. Two years after Neil and Buzz landed on the moon, America led the world in awarded PhDs in science and engineering and math. Today we are not even on the first or second page. The motivation," as you were just speaking earlier, "the motivation of our youth is the most important thing we do for our nation's long-term security and prosperity. NASA's role in that can be as critical as it was in the sixties if the taxpayers fund true research and exploration."

Manned space flight and exploration is one of the last remaining fields in which the U.S. maintains an undeniable competitive advantage over other nations. To walk away is shortsighted and irresponsible. By killing the exploration program in favor of a vaguely defined "research and development program," you are guaranteeing that the Chinese, the Russians, and others will be closing the exploration gap. We will be dependent on the Russians in the short term for rides to the International Space Station, and worse, we will be forced to play catch up to the Chinese and the Russians in the future. The Chinese, who are aiding and abetting the genocide in Darfur, and the Russians, who have more of bad things that we all know through history. When that time comes I fear that the U.S. will no longer have the resources or the political support to relaunch our human space flight program.

James Lewis with the Center for Strategic and International Studies said he sees this decision "as a confirmation of America's decline." In the interim our space flight and manufacturing base will wither. We will be forced to spend far more to recreate our current capacities at a later date.

The editors of "Space News" argued similarly that this could have a devastating effect on the U.S. propulsion industrial base, endangering DOD launch operations. This also has very serious national security implications. Alternative commercial vehicles will not be available much if at all sooner than the Ares I rocket. Worse, these alternative contractors have no experience in manned space flight and the safety measures necessary.

As Norm Augustine said, "Space operations are among the most demanding and unforgiving pursuits ever undertaken by humans." NASA's workforce has forty years of experience, having learned by tragedy and success. The Constellation program contractors have been working on these issues for seven years. As a result of your plan, at the end of this decade we will only have a few years of flights to the International Space Station followed by a fleet of low Earth orbit vehicles with nowhere to go. Worse, you will have no exploration vehicle system to go beyond the Station. Above all, the budget proposal leaves NASA with no clear exploration mission goal. An agency with no vision or leadership will slowly decay. It will no longer be a place for our nation's best and brightest to work. What we need is a NASA with vision, expertise, and support to maintain and grow our competitive advantage in space exploration.

And with that, Mr. Chairman, I just yield back and I thank you.

NASA—CONSTELLATION

Mr. MOLLOHAN. Okay, thank you Mr. Wolf. Dr. Holdren, because I am going to have to leave. I am going to give you an opportunity to, in a relatively uninterrupted way, speak to the question of NASA's decision to revamp its exploration program, to essentially cancel Constellation and to move forward as proposed in your budget. I note that prior to your commenting, we were all excited, I think, those of us who are interested in space exploration, when President Bush announced what he described as his Vision for Space Exploration. The problem with that was not the expression of the vision. The problem was in the funding of the programs that were necessary to fulfill it. So really what started as an expectation ended up being a considerable disappointment as the program fell behind in many different ways and was, as a result of incredible underfunding and at the recommendation that we probably would have to be spending $3 billion, $4 billion more a year on it. Not to catch up, but just to keep the Constellation program going.

I say this not making judgment about the administration's proposal, frankly. But in fairness, noting where this administration found itself after its election. It proceeded, I thought, extremely responsibly by calling on Norm Augustine to head a review commission. We all have confidence in Norm Augustine because of his service to the country and his considerable industrial experience. The Augustine Report, which was the beginning of NASA's and the administration's review of the exploration program, came essentially to the conclusion, certainly implied the conclusion, that is reflected in the President's budget request.

The failure of President Bush's vision because of his lacking in the application of adequate resources is measured in a number of different ways. The gap that increasingly grew between the termination of the space shuttle and the coming online of another transportation system for U.S. human access to Station, I think, is probably one of the most glaring measurements of the failure of President Bush's space exploration program.

So it is, I certainly recognize, and I think most members of this Committee who work so closely with the science accounts, understand how inspirational a grand vision of space exploration can be, and how it can drive the decision making of youngsters to go into science and to go into research. We saw that certainly with Apollo. But it has to be real, and it has to be not only articulated but it has to be supported with resources. And if not, then it is in fact a hollow vision.

Again, that is all not by way of passing judgment on the administration's request, or its proposal, for exploration in and of itself, or in regard to Constellation. But simply to put in perspective this issue as I invite you to comment on it, as I say, in a fairly uninterrupted way which might be your only opportunity to comment on it in a fairly interrupted way. Not only on this Committee, but you can expect when you come up to have to flesh out the rather skinny presentation that we have with regard to the President's proposal at this time. There is, as you know, an awful lot of interest in this, and concern as expressed by the Ranking Member. Dr. Holdren.

Dr. HOLDREN. Thank you. Well, certainly there will be more opportunities and there will be more detail forthcoming. And I know the Administrator is going to be up on the Hill tomorrow testifying. But as NASA has more time to pull all of the details together there will certainly be a lot more detail forthcoming.

But let me start by saying that as the Ranking Member's comments indicate, there is certainly a difference of opinion in the space community about whether this is a good idea or not. The Ranking Member mentioned, as you did Mr. Chairman, the Augustine Commission. Well Norm Augustine has strongly endorsed the new proposal. He says "By making a significant investment in creating commercial capabilities to take humans and cargo to low Earth orbit, overseen from a safety standpoint by NASA, this will drive competition, lower costs, open new markets, and make space more accessible. Similarly, by allocating the technology resources highlighted in our report as being necessary it will be possible to lay the foundation for travel beyond low Earth orbit, including destinations such as the asteroids, the Lagrangian points, Mars' moons, and Mars itself, as well as revisits to our own moon."

The key point is that what the administration's plan is aiming to achieve is not a retreat from the exploration of space, not an abandonment of human space flight, but an approach to doing it that invests in advanced technologies to do it better, to do it cheaper, to do it faster, to do it safer, and to do it in a way where we can match the mission to the resources. I think a goal of being able to operate successfully in deep space is more important as the guiding light for the program than any one destination. And our goal is to be able to operate in deep space, to be able to reach a variety of destinations to deploy the technologies that can do that in an effective way.

Buzz Aldrin, the first person to set foot, second person to set foot on the moon, after Neil Armstrong, also endorsed it. He says, "the truth is, we have already been to the moon some forty years ago. A near term focus on lowering the cost of access to space and on developing key cutting edge technologies to take us further faster is just what our nation needs to maintain its position as the leader in space exploration for the rest of this century."

So obviously, there are differing views. We could get in warring quotations probably for a long time. But there are a lot of prominent folks, including the folks on the Augustine Commission, Sally Ride, the first U.S. woman in space, who strongly endorse the program. Obviously there are differing views. I think some of those differences are going to shrink as the details come out and people have the chance to discuss them in a variety of forums.

I would point out that we were already going to be dependent on the Russians no matter what we did the moment the decision was made. And it was made in the Bush administration. I think it was made correctly, that we needed to retire the shuttle in 2010. Now under the new plan we have provided a budget to fly out the manifest into 2011 if that is necessary, to do it prudently and safely. But whatever else we did, we were going to have a period of dependence on the Russians to lift U.S. astronauts into low Earth orbit.

We think under the new proposal that we will be able to shorten that period below what it would likely have been in Constellation. The Augustine Commission conclusion was that Constellation would not be able to take astronauts to low Earth orbit until 2017 or 2018. That would have been after, under the program of record, the International Space Station would have been crashed into the ocean in pursuit of savings to pay for Constellation. The Augustine Commission characterized the Constellation program as unexecutable. And they concluded that if Constellation were funded in a manner that could return U.S. astronauts to the moon before 2025 it would cost between $45 billion and $60 billion more between 2010 and 2020 than what was programmed under the 2010 guidance.

So we had a big challenge already with the Constellation program, in terms of being able to go where the original vision called for it to go, when it called for it to go there, as again you pointed out Mr. Chairman in your remarks. And the administration's task was to find a way forward for the space program that would maintain U.S. leadership in space, that would maintain the capacity to explore above Earth orbit, that would make it better and cheaper, and that would do it within the bounds of something that we could afford in difficult financial times.

I could say more but I think it probably would be better to have some back and forth.

NASA—HUMAN SPACE EXPLORATION

Mr. MOLLOHAN. There is this woe that this is a real threat to our human exploration of space. That is going to be a concern. That the United States has just relegated itself to second place in that area. Speak to that. How does President Obama's way forward with regard to human exploration, access, when we get back with our own transportation system, one approach versus the other. Speak to this whole concern of human, USA human access to space.

Dr. HOLDREN. By extending the International Space Station we are ensuring that there are going to be more U.S. astronauts in orbit over the next decade than there would have been if we had crashed the Space Station into the ocean in 2016. That is point one. Point two, in terms of deep space exploration, in terms of getting humans beyond low Earth orbit, we think the way to do that is with better technologies. We think NASA has been underinvesting in advanced technologies for decades. And the result is that we were talking about going back to the moon, and imagining we could go beyond someday to Mars, with chemical rockets very much like those that we had in the sixties and seventies. We need to do better if we are to take astronauts as far as Mars and the only way we are going to do it is with better technology. The only way you are going to get that better technology is making investments in developing it.

We have a whole range of technologies that we are able to pursue if we wind down Constellation, and take better advantage of the very large sums of money that were going into that program, which were considerably more than foreseen at its inception. That makes available money to do research on advanced heavy lift propulsion, advanced deep space propulsion, on orbit refueling and fuel storage, a variety of technologies that can make it practical and affordable for U.S. astronauts to go into deep space. If the Chinese and the Russians keep on with a trajectory that is based on the old technology we are going to leapfrog right past them with an approach that invests in American ingenuity to do better.

Mr. MOLLOHAN. Thank you. Again, I am sorry to have to leave the hearing. I have asked Mr. Ruppersberger if he would dedicate the rest of the afternoon, and he was kind enough a while ago to say that he would do that. I would ask that he come and take the chair and call on Mr. Wolf.

NASA—CHINA AND RUSSIA

Mr. WOLF. Thank you, Mr. Chairman. Many have characterized this proposal as ceding leadership in manned space flight to other nations. Charles Krauthammer wrote that, "Decades from now there may be a robust private space industry," but to quote he said, "in the interim space will be owned by Russia and then China." What are the implications of abandoning Constellation at the same moment that other countries, particularly China, are setting specific space exploration goals?

Dr. HOLDREN. Well, Administrator Bolden and I wrote a letter to the editor of the Washington Post indicating that we disagreed with Mr. Krauthammer on virtually all of his conclusions. I do not think we are, as I have indicated, I do not think we are ceding leadership in space to the Russians and the Chinese at all. As I said, I think we are going to develop technologies that are going to maintain American leadership in space. Advanced technology has always been our strength in this country and it will continue to be our strength. And I think that will apply to deep space as much as it has applied to other domains.

If the Chinese are able to get back to the moon fifty years after we did it, I do not think that demonstrates anything about Chinese leadership. We were there in 1969. We went back five more times into the 1970's. Anybody who thinks that the Chinese lead because they get there fifty years later should talk to Neil Armstrong and Buzz Aldrin. We are going to stay ahead of them because we are going to have better technology than they do.

NASA—CONSTELLATION

Mr. WOLF. Was the decision to scrap Constellation fully considered from a national security perspective? And was the National Security Council part of the decision making process?

Dr. HOLDREN. Yes, the process that we ran in the White House after we received the report of the Augustine Commission included the National Security Council as well as the Office of Management and Budget, OSTP, and of course it continually included NASA with the folks at NASA continually in touch with the national defense community as well because they have many overlapping interests and responsibilities. So the short answer to that question is yes.

NASA—JOB LOSSES

Mr. WOLF. What do you anticipate as the impacts of this decision on the workforce, civil service and contractors? And how many jobs will be lost and when? And what measures do you plan to take to minimize the impact to job losses and the negative impact on the industrial base?

Dr. HOLDREN. First of all, the job losses are obviously a very important concern. They are important to everybody. They are important to the Congress. They are important to the President. This is not a time in which we would lightly entertain job losses of any sort. We knew we were going to be in for job losses in connection with the shuttle program as soon as the shuttle was retired. There was no option that would have avoided significant losses in the shuttle program as soon as the shuttle had retired.

We think this plan does more to mitigate those losses by creating opportunities. It is going to create opportunities, as I have indicated, in heavy lift propulsion, in advanced space propulsion. We have a plan to invest considerable additional resources in the Kennedy Space Flight Center to upgrade its capabilities to make it a launch center for the 21st century, to increase its capacity to support the increased number of missions we are going to have. We are going to have more robotic missions. We are going to have an increasing number of commercial missions launching from the Kennedy Space Center.

With respect to the jobs in Alabama, the Marshall Center, which has tremendous expertise in rocketry, obviously, is going to lose some jobs when Constellation is wound down. But it is going to gain some jobs in heavy lift propulsion research and in other advanced technology research in which the capabilities there are unmatched anywhere. This is a consequence. Anytime there is any change in direction you are going to have some jobs lost in some domains, other jobs gained. We are making every effort to maximize the number of jobs that will be gained by the changes in this program.

Mr. WOLF. So what is the number of jobs? The question was, what is the number of jobs?

Dr. HOLDREN. I do not think anybody knows exactly, Congressman, what the number of jobs will be. All of those analyses have a little bit of slop in them.

Mr. WOLF. But you must have looked at——

Dr. HOLDREN. Yeah, we have——

Mr. WOLF. So tell us what you——

Dr. HOLDREN. We have looked at job losses. I think we are looking at something like 5,000 job losses in Florida. And we think we will be able to restore at least something in the range of 1,700 to 2,000 of those with programs that we have already identified. And those are the jobs we were going to lose in the shuttle program anyway. The number of jobs at risk in Alabama, there are 2,500 civil servants employed at Marshall. Some of those jobs will presumably be lost but many of them will be retained because of the additional research and development efforts that will go on there.

Mr. WOLF. Thank you, Mr. Chairman.

Mr. RUPPERSBERGER. [Presiding] Okay, I think on the list I am next. And then John, I think you are. I want to get into three areas continuing some of the questioning on the Constellation, get into NOAA, and then the final is the restrictions on imagery resolutions for commercial satellites. There is a big concern there and I think that if we do not look at that more thoroughly that France, Germany, Spain, Italy are all talking about doing what we do right now and it looks like it is another ITAR. So I would like to get into that.

NASA—CONSTELLATION

But let us get back to the Constellation. What you are, and we want to do what is right for America. And, you know, the administration is there, we want to work with the administration. But, you know, right now this came out of nowhere from where we are sitting, those of us who deal in the space program, whether it is intelligence, defense, or this Appropriations Committee. And we talk, the concept sounds great. The fact that we are putting a lot of money into research and development, and we have not done that for a while. In fact, if you look at, I think, the failures of our space programs, things that really are still classified, we cannot talk about all of them. A lot of it is because we took a lot of money away from research and development and testing and the things that needed to be done. You can have a major contract with one of the big boys, whether it is Northrup, or Boeing, or Lockheed, you know, all the big corporations. And they would have these contracts, and then they would do the research and development along the way. It would be over price, over time, and half the time the bird would be so big because every three-star wanted everything on it and nothing was going to happen. So I think your concept is good.

My concern is that it is happening very quickly without a plan, the way we see a plan. And we need to have a plan. And then let us evaluate that plan. You look at this county, some people feel that if you control the skies you control the world. When Sputnik came out we responded as a country in eight years and put a man on the moon, and that really helped us do the research and development to get us where we are now as being dominant in space. But as you know, we have had a lot of failures. And that is what I am sure you are focusing on now. But I am worried about the details, and doing something too quick, too soon. It almost reminds me of the healthcare bill. And, you know, when you, when you are focusing on something as important as our national security, and where you are going to be going, I feel the commercial is very important. I feel in the area of defense and intelligence we have been way behind and we have lost money where we could have one, four satellites to one because of the traditional ways that the, I call it, not out of disrespect, but kind of a joke, the old bulls, admirals, and generals, or whatever. And just wanting not to take the risks that maybe we took when we put a man on the moon years ago.

NASA—MARS

But where the concern is, and I am going to ask you this question, is it our intention to put a man on the moon again? Or a man on Mars again? Is that the administration's intention?

Dr. HOLDREN. I think in short yes. Mars, everybody agrees I think Mars is the ultimate destination. We are not ready to put a date on that. There was no date, by the way, on going to Mars even in the Constellation program. But yes, Mars is the ultimate destination for human space flight beyond low Earth orbit. The President has not abandoned that. Administrator Bolden has not abandoned it. We will ultimately put people back on the moon, when we are ready to do interesting things with them on the moon surface. The problem with the Constellation program is that we would at most have been ready to put U.S. astronauts in the vicinity of the moon around 2028, according to the Augustine Committee. And we would at that time have not had the capability to put them on the surface, because we would not have been able to pay for the lander under the budget that was foreseen.

We will go back to the moon and we will ultimately get people on Mars. But when we do it we will do it in a way that makes sense, a way that we can afford, and a way that is safer for the astronauts.

Mr. RUPPERSBERGER. The way the administration, the perception at least from my perspective, is that, "Well, we are going to go where we need to go in space, but we are going to let the commercial side take more control." And I do not have an issue with that. And some, as I said before, in defense with some intel. But if you are going to put a man on the moon, commercial has not had the research and development. They do not have the capacity at this point to put a man on the moon or Mars. And by the way, why that is relevant, too, is because our younger generation, I feel, is not going to space anymore because these programs are out there forever, it takes forever to go where we need to go. And, you know, that is, the younger generation really needs to be more active and we need to focus more in this area of space.

Also, we need to get the country excited. Because people are tired. They are just not used to having, let me say it this way. In the old days, an astronaut was as popular as an NFL quarterback. These days that is not the case. And I think the country just is not excited about going to the Space Station and back.

I am going to get back, though. What is the plan? I mean, I am hearing theory but I am not hearing detail. And until you have detail, and we are sitting here as appropriators, and we are worried about national security. And, you know, it is such a big decision on where we go and how we are going to develop our space and science, and how we are going to control the skies. I am worried we are going too quickly on this thing.

Dr. HOLDREN. Okay, let me respond on a couple of points.

Mr. RUPPERSBERGER. So educate us.

Dr. HOLDREN. First of all, I want to be clear. We are not proposing to use commercial to go to the moon or to go to Mars. The proposal is to turn over the most straightforward part of the task, which is lifting cargo and astronauts into low Earth orbit, to public-private partnerships in which the private sector plays a bigger role than it has played in the past. And what has basically changed here is the acquisition model. We have relied on the private sector to build the technologies that take our astronauts into space from the beginning. The Mercury capsule was built by McDonnell. General Dynamics launched it with an atlas converted from an ICBM. Rockwell International built the space shuttle. What is changing is the acquisition model, where the idea is we will buy the service and the private sector, investing substantial amounts of its own money, but also some government money at the outset, will deliver that service. But the technology that we have been using to take U.S. astronauts into space has always been built by the private sector.

At the same time, by turning over more of that task of lifting cargo and astronauts into low Earth orbit to the private sector we are going to free up NASA's resources to do the more demanding, tougher, cutting edge jobs for which NASA is uniquely suited. NASA is going to have——

Mr. RUPPERSBERGER. Give me an example?

Dr. HOLDREN. NASA is going to have the responsibility for developing in-orbit refueling capabilities. NASA is going to have the responsibility for the development of advanced heavy lift capability. NASA will have the responsibility for developing the advanced space propulsion engines that can get us more rapidly to destinations like Mars. If we try to use chemical rockets to go to Mars we are going to have our astronauts out there for so long we are going to have a big radiation exposure problem. We need to do this in the right way, and the right way to do it is advanced technology. And NASA is the operation that is going to bring us that technology. We are not turning the whole space program over to the private sector by any stretch of the imagination.

You are right to ask for more detail. This plan awaited, first of all, the completion of the Augustine report before the administration was even going to consider in any detail what the options were, and which option it was going to choose. It wanted to have the Augustine Report. We got the Augustine Report. We set up an interagency process in the White House to consider the findings of that report, to consider and develop and cost out the options. NASA was involved in that. NSC was involved in it. We in OSTP were involved in it. We presented a wide variety of options over a period of time and we ended up with a decision. This is not a decision that was reached without a lot of input from folks in NASA. It was not a decision that was reached without input from the private sector, from our experienced contractors who are not all, by the way, small operations. The Augustine Committee had an exceedingly open process in which they talked with virtually everybody, visited the major space centers, and so on. But the details do still need to be fleshed out.

NASA has been working on that very hard ever since the decision was made to go in this direction, I think you will be seeing from Administrator Bolden, and others from NASA who will come up here, the fleshing out that you rightly want before you reach a conclusion about whether this is a viable pathway. I have seen enough to believe it is.

Mr. RUPPERSBERGER. There are other, I will get to other questions in another round, so John, I do want to say this, though. One of the focuses that I feel has to be looked at is the DOD, intel, and NASA collaborating a lot more. And a lot of times DOD and intel to an extent hold their satellites close to the vest when it is not necessary.

Dr. HOLDREN. I know that.

Mr. RUPPERSBERGER. And we need to open that so that maybe a defense satellite or an intel could be used by NOAA, or whatever. That is something I would hope you would focus on. John?

NASA—AUGUSTINE COMMISSION REPORT

Mr. CULBERSON. Thank you. Thank you very much, Mr. Chairman. Dr. Holdren, I heard you say just a moment ago that your plan, you were waiting for the Augustine Commission Report because you would not think of releasing this until they had their report, right?

Dr. HOLDREN. Of course.

Mr. CULBERSON. So you developed this plan before you had even seen the Augustine Report, did you not?

Dr. HOLDREN. No, I beg your pardon. I said——

Mr. CULBERSON. That is what you said.

Dr. HOLDREN [continuing]. We were waiting for the Augustine Report to look at the options.

Mr. CULBERSON. I think that was what you said.

Dr. HOLDREN. No, excuse me, sir, but that is not what I said. I said we were waiting for the report——

Mr. CULBERSON. Yeah, I think that is what you just testified.

Dr. HOLDREN [continuing]. So we could see, we were waiting for the report so that we could see how it characterized the different options. We had not decided——

Mr. CULBERSON. You were not even thinking about this and planning this before the Augustine Commission released its report. Are there any memos, any discussions at your office, at the White House of cancelling Constellation before the Augustine Commission released its report?

Dr. HOLDREN. I would have to go and look to see if there was any consideration of that. We knew, sir, from many other sources, from many other analyses, that there were very serious criticisms out there about the viability of the Constellation program.

Mr. CULBERSON. I know, I was wondering what you——

Dr. HOLDREN. So it would be surprising if nobody involved in any of these discussions had mentioned those analyses. But certainly I can assure you no decision had been made about what course——

Mr. CULBERSON. A decision had been made but you were waiting to move until, I heard you just testify you were waiting, you would not have announced this before.

Dr. HOLDREN. We would not have had anything to announce before——

Mr. CULBERSON. But you were already contemplating this.

Dr. HOLDREN. No, we would not have had anything to announce. Believe me, the President did not know what he wanted to do. We did not, in the early phases, even have a new NASA administrator.

NASA—CONSTELLATION

Mr. CULBERSON. Let me also ask you, if I could, excuse me because our time is so limited, I also heard you just say that you contemplated, this was developed with the input of NASA deputy administrators and, you know, you talked to folks out in the field. Yet the field center heads, who are your best experts, Mike Coats who is a prince, he is Director of the Johnson Space Center, these men and women are the best in their field. And these field directors, the directors of the field centers, your associate administrators and field center heads were not even told of the final details of the plan to cancel Constellation until just a couple of days before its release. They were not consulted with.

Dr. HOLDREN. They were consulted early in the process and during the process about the options, the characteristics of different possibilities.

Mr. CULBERSON. That is not a direct answer. Your testimony was you consulted with NASA directors and associate administrators, and it is a fact that your associate administrators and your field center heads said they were not told about the decision to cancel Constellation until a couple of days before the announcement.

Dr. HOLDREN. Congressman, with respect you are not distinguishing between consulting them during the process of developing a decision——

Mr. CULBERSON. Well you said consult them about options. I am talking about the cancellation. You are attempting to cancel Constellation, right?

Dr. HOLDREN. Yes, that is correct.

Mr. CULBERSON. Okay. They were not consulted, were they?

Dr. HOLDREN. They were consulted in the whole process.

Mr. CULBERSON. Did you tell them you were going to cancel Constellation?

Dr. HOLDREN. We did not tell them until we told them, sir.

Mr. CULBERSON. Did you ask them what they thought about cancelling the Constellation program?

Dr. HOLDREN. I could not tell you who talked to which director when about the possibility of cancelling the Constellation program. The Augustine Committee met with all of those folks.

Mr. CULBERSON. No, no, no, you, I am not talking——

Dr. HOLDREN. We were obviously contemplating a wide range of possibilities.

Mr. CULBERSON. Yeah. Forgive me, because our time is so short. I am not talking about the Augustine Commission. I am talking about you and your office, and the folks that sit behind you that work for you. Did you or any of your staff consult with and ask any of the field center heads, or any associate administrator at NASA, what is the impact on American leadership in space if we cancel Constellation?

Dr. HOLDREN. I did not ask any center director that question.

Mr. CULBERSON. Okay.

Dr. HOLDREN. My assumption is that folks in NASA did.

Mr. CULBERSON. Your assumption? You are a scientist, you do not assume. You know what that stands for.

Dr. HOLDREN. I could not tell you whether any members of my staff talked to those particular people or not. I know their views——

Mr. CULBERSON. Okay.

Dr. HOLDREN [continuing]. Were taken into account in developing the Augustine Report.

Mr. CULBERSON. Their views were taken into account? They were not told of the cancellation until two days before the announcement.

Dr. HOLDREN. This is a different question. The question of when people get told about a decision, and what consultations go into the decision are two different questions.

Mr. CULBERSON. The reason for the question, Mr. Chairman, is very important. Because Dr. Holdren has testified, you just said flat out that your plan is going to reduce the gap. You are going to be able to reduce the gap, we are not going to have to rely on the Russians for as long. I heard you say that. And that is a statement which you as a scientist, I am confident, do not make statements unless you have got verifiable facts that you can back that up. You did not clearly consult with or ask any of the field center heads what will be the gap, how long will the gap be if we cancel Constellation and turn this over to the private sector? And since that conversation did not occur, you have no basis to make that statement from field center directors.

And let me also drive this point home. How many, I want to know how many private contractors you visited with, or asked their opinions. You say that you can shorten the gap with the private sector. Did you or anyone from your office ever meet with Boeing, or Lockheed Martin, or ATK about what the effect on the gap will be if we turn it over to the private sector guys.

Dr. HOLDREN. I would have to ask the people in my office whether they did. But the basis for that statement was the Augustine Commission Report, which said that there was a considerable probability that the private sector could start putting U.S. astronauts in Earth orbit by 2016. And the Augustine Committee view was that Constellation would not be able to do it until 2017——

Mr. CULBERSON. Someone from your office did?

Dr. HOLDREN. Sir, I cannot tell you who all people in my office talked to.

Mr. CULBERSON. Now certainly——

Dr. HOLDREN. I have a very energetic and dedicated staff. They talked to a lot of people.

Mr. CULBERSON. The Augustine Commission looked at a lot of different options, and that was one of them clearly. And the statement, though, you made though, that we are going to shorten the gap if we follow this proposal you have laid out, on what do you base that? Who——

Dr. HOLDREN. I base it in part on the Augustine Committee Report, which concluded that that was a likelihood.

Mr. CULBERSON. Okay. Let me, if I could also finally, Mr. Chairman, because I know we are short on time, ask Dr. Holdren, you directed the administration has essentially as I know has told NASA to go ahead and begin to start winding down, get ready to shut down Constellation, right? You have already sent out those orders?

Dr. HOLDREN. Number one, I have not sent out any orders.

Mr. CULBERSON. No, the White House, the administration.

Dr. HOLDREN. To my knowledge, and I have seen a letter that Administrator Bolden wrote in response to a letter from Congressman Alderholt and some others.

Mr. CULBERSON. And me.

Dr. HOLDREN. The NASA Administrator has not sent out any orders to contractors to start cutting things down. They are complying with the law, they are asking, because the President's proposal is to wind down Constellation, they are asking what it would cost to do so. That is a different thing than saying stop work, sir.

Mr. CULBERSON. Okay. The reason, Mr. Chairman, is because we put in this Committee, and we did so quite properly, put into statute language, Mr. Chairman, that says that none of the NASA funds provided herein for prior years shall be available for the termination or elimination of any program, project, or activity of the architecture for Constellation, nor shall any funds be available to create or initiate a new program, project, or activity unless such program, termination, elimination, creation, or initiation is provided in subsequent appropriations act.

Now that is statute. You cannot in any way alter or change or Man Launch Space Program because that is our job.

Dr. HOLDREN. Without the consent of the Congress, that is absolutely correct.

Mr. CULBERSON. NASA can't use one nickel of the money appropriated from this Subcommittee to change, alter, or in any way the Man Space Program.

NASA—AMERICAN LEADERSHIP

And I would say I share everyone's concern on this Committee that we—you are proposing surrendering Little Round Top. You are surrendering the high ground to the Chinese, to India, to our friends and foe alike, and it is something America has never done in its history, and I am frankly embarrassed.

Dr. HOLDREN. Well, I don't agree with that characterization, sir, with all respect. We do not intend to surrender leadership.

Mr. CULBERSON. I am mortified. Embarrassing and mortifying that America would—our American President would voluntarily surrender leadership of the world in science and space exploration and surrender the high ground to our enemies is mortifying, embarrassing, and unacceptable.

Dr. HOLDREN. Sir, that is not what we are proposing to do. We are proposing to maintain U.S. leadership with what has always been our strongest suit, which is advanced technology.

Mr. RUPPERSBERGER. I think one thing the statute did say, it did give the right to modify, I believe. Is that correct? I just heard that from staff. That is the statute. Mike, do you have any questions? We have 332 who have not voted.

Mr. HONDA. Thank you, Mr. Chairman. If we leave and come back I will reclaim my time when we get back.

Mr. RUPPERSBERGER. Okay.

NASA—COMMERCIALIZATION OF SPACE EXPLORATION

Mr. HONDA. The question I have is I guess the choice between going commercial, privatization of space exploration versus the government doing it in terms of advancing technology and looking at new technologies.

When we are looking at turning over the task of space exploration in lower orbit, open it to commercialization or commercial efforts are we giving up our position on creating new technologies? Or what role do we play in terms of developing new technologies?

Dr. HOLDREN. Well first of all the proposed plan greatly increases the investments we are making in NASA in developing new technologies. New technologies for heavy lift, new technologies for propulsion in deep space, new technologies for refueling in orbit. We think we need a range of new technologies to make human exploration of deep space practical, and it is our intention to develop those.

The increased role of the commercial sector in this plan is confined to an increased role in lifting cargo and astronauts into low Earth orbit, and we think for that task that the rapidly developing commercial space flight sector can make a very important contribution.

Mr. HONDA. So you are saying that we are dividing our responsibilities that we will do the things that they need to have in order to put their payload up.

Dr. HOLDREN. Well again, they already have rockets, they are designing additional ones.

Mr. HONDA. I understand that.

Dr. HOLDREN. They have already been building rockets for our program.

Mr. HONDA. I am not trying to argue with you.

Dr. HOLDREN. No, I know, I am trying to answer your question.

Mr. HONDA. Saying that we are going to be developing the technology for them to use to put their payload up.

Dr. HOLDREN. We have already done some of that. They already have some of the technologies they need. It is an ongoing interaction. It is going to be a partnership. It always has been.

Mr. HONDA. Will the partnerships increase in terms of them having a greater role——

Dr. HOLDREN. Yes.

Mr. HONDA [continuing]. And bear the expense of putting up the payload?

Dr. HOLDREN. And they are expected to be willing to do that because they will have customers other than the U.S. government. As again they already do in putting up communication satellites and so on.

Mr. HONDA. For us to recoup the investment we make, what responsibilities will with they to pay back into the coffers?

Dr. HOLDREN. You are now exceeding my competence. I am not an expert in the kinds of contracts that will be developed for this purpose.

Mr. HONDA. No, but there has got to be some sort of a basic concept of we invest the money, they take advantage of it and make money, and where does that enrichment go to in terms of——

Dr. HOLDREN. Well part of the enrichment goes to maintaining U.S. leadership in space, because it frees up——

Mr. HONDA. Well if you look at—I understand that, you know, we did that with technology in terms of IT and——

Dr. HOLDREN. Sure, we do it across the board.

Mr. HONDA [continuing]. Other areas, but very little of that money that we put into it comes back to public education, postgraduate work where we lead in that. And if we are going to continue to lead that and if we have that confidence that we are going to be able to do that we have to find other ways to be able to, you know, sustain that in the long term.

Our Congress, every time we talk about other countries, we talk about them as if they were folks who are not going to be playing as a team. Are we looking at working with Russia and China and Japan and the other countries who are going to space as partners?

Dr. HOLDREN. We do that already, sir, to a very substantial extent. We have up there the International Space Station which we are extending to 2020.

Mr. HONDA. Yeah, but we——

Dr. HOLDREN. We have got Russians up there, we have Japanese, we have Europeans. They are helping to provision the station. Their launchers are taking cargo to the Space Station regularly. That will continue to happen. There are lots of respects in which we do partner with other countries to the Space Station regularly. That will continue to happen. There are lots of respects in which we do partner with other countries to get these tasks done in concert.

Mr. HONDA. And we do that and then we withdraw our partnerships at times don't we? And so——

Dr. HOLDREN. Well, I think——

Mr. HONDA [continuing]. My concern is being consistent in our partnership and our commitment, but also being consistent and—I am trying to say it way that I am not going to offend my colleagues—but we seem to criticize or put them out there as if, you know, they are going to be or constant enemies, and our congressional move the past few years where we disallowed our companies to work overseas to do the launching, we lost of lot of market share in the world. And so you know, we either do it right and be consistent, and you know, if Congress went off on one end or the other, that somebody's got to say, you know, let us just be consistent about this thing. You know, we are very schizophrenic about our global relationships, and I think that we need to do some work in that area too.

Dr. HOLDREN. I would agree with that. There is obviously a longstanding tension between competition and cooperation in a lot of these domains, and you have to decide when you are going to cooperate and when you are going to compete. We are doing a lot of cooperation in space.

Mr. HONDA. Right. And I don't think that we have a problem understanding that because we do that in Texas, we do that in California in terms of, you know, the technologies. Is we have to be able to do that with come confidence with other countries, and at the same time they have a problem with us too I am sure, because they have a history from their point of view, and using a minimum of understanding that we deal up right now just in the area of global warning, we end up sharing the IPs and not fight over it.

I guess the other thing we need to do if we are going to move into this arena is to start looking at how we talk about and how we treat our relationships as we move forward in the technology.

Dr. HOLDREN. No, I agree that is important. I do think we made our partners very happy by extending our commitment to the space station rather than saying for reasons of our budget we have to crash it into the ocean in 2016.

Mr. HONDA. Real quick question.

Mr. RUPPERSBERGER. We are going to have to adjourn the meeting temporarily—we will come back. There are three votes, two after this, then we will come back.

Dr. HOLDREN. Okay.

Mr. RUPPERSBERGER. It will probably be about 20 minutes.

NASA—SATELLITES

Mr. HONDA. So let me just finish my question though. At Lockheed, which is one of the contracts, they are developing some satellites for our Constellation Program, correct?

Mr. RUPPERSBERGER. We have ten more votes.

Mr. HONDA. And my understanding is that they are going to have to stop at a certain point, but we will have approximately four satellites up there to continue our mediums to put up satellites so that we have an increased efficiency and geo positioning and controlling kinds of things that we control with these satellites both commercial and military.

Dr. HOLDREN. Right, those aren't part of the Constellation Program.

Mr. HONDA. They are not?

Dr. HOLDREN. They are not

Mr. HONDA. Then why is TSAT, I understand that TSAT is going to be set aside or we are not going to be funding it beyond a certain date, and they are already working along those——

Dr. HOLDREN. I am not sure what the connection is between the satellites you are talking about and Constellation Program.

Mr. HONDA. Does anybody else know?

Dr. HOLDREN. Those are separate. The Constellation Program consists of the Ares 1 rocket for lifting crew and cargo into low Earth orbit; the Ares 5, which is a heavier rocket; the Orion Crew Capsule; and the Altair Lander, which was intended ultimately to land on the moon. But there are no satellites in the Constellation Program.

There are a whole variety of satellite programs that are very important that we are continuing to fund.

Mr. HONDA. So TSAT has nothing to do with this then?

Dr. HOLDREN. Yeah.

Mr. HONDA. Then can you help me understand why the future funding of that is going to be on hold where the next generation they are looking at to be able to produce the system that we have out there and increase our dominance and control of the technology and satellite and geo positioning? And maybe I can get a response back in writing.

Dr. HOLDREN. Yeah, this is a military satellite, but I would have to get back to you on the details. I am not familiar with the TSAT Program or what's happened to its budget. So I would have to look into that, sir, and we could get back to you.

Mr. HONDA. Okay.

Mr. SCHIFF. Mr. Aderholt?

Mr. ADERHOLT. Mr. Chairman, we have two, five-minute votes after this, and my question is going to take a little longer. Could we just recess for just for about five or ten minutes and then——

Mr. SCHIFF. Well, if you don't mind, Mr. Aderholt, I have got a short question. Maybe I can get that in now.

Mr. ADERHOLT. Well then I just defer. Go right ahead.

Mr. SCHIFF. Okay, thank you.

Mr. ADERHOLT. I will go vote and then I will come back. Okay.

NASA—PLANETARY SCIENCE PROGRAM

Mr. SCHIFF. Super. Mr. Holdren, I wanted to ask you about the Planetary Science Program. The President's budget does a great job of funding earth science missions and continues funding for current planetary science missions, but it doesn't do much to move future planetary science missions into the formulation stage, in particular the outer planets flag ship mission to Europa is not moved into the formulation phase. The budget mentions that NASA is waiting for the results of the Planetary Science Decadal Survey before formulating the mission, but this mission was recommended in the last decadal and has been ready to begin development for several years, so that seems just another delay, another excuse for delay.

Those of us that have been strong supporters, but don't understand why we continually—it gets approved by one decadal and we got to wait for another decadal, and why isn't NASA funding the development of an outer planets mission in 2011?

Dr. HOLDREN. I don't have the answer to that off the top of my head, it is another one I will look into and get back to you. I am not sure what the answer is.

Mr. SCHIFF. Okay, I appreciate if you would get back to us on that. That was the only short question I had.

Let me start with the next one and we will see how far we can get.

NASA—HEAVY LIFT CAPABILITY

The new budget discusses heavy lift, but not with a lot of detail. The only time line mentioned is a vague statement that we should have a new heavy lift first stage engine by 2020, developing a vehicle will then take many more years leaving us without a heavy lift capability until 2025 or 2030. All though the commercial space flight companies are making great progress they don't have plans for heavy lift.

What would be necessary to get us a heavy lift vehicle by 2020 to move up the timetable, and can the technologies outlined for development using funds currently devoted to Constellation reduce the size of the heavy lift launcher we might need?

Dr. HOLDREN. Let me take the last question first. Certainly some of the technologies that are going to be explored under the new plan can reduce the need for heavy lift. For example, if you can develop and demonstrate in-orbit refueling then the need for how much mass you have to put up at one shot can be reduced and you can have a smaller heavy lift capacity than you would otherwise need.

There are a variety of other advanced technologies that can effect that. For example, if you get advanced space propulsion that doesn't need as much chemical fuel to go where you are going you can again reduce the amount of mass you have to put up there.

There is no very specific timetable beyond the general goal you mentioned in part because we don't know until we start reinvesting in technology how fast we can make progress and what the most attractive possibilities will be that could be converted into real operational systems. So obviously this is something that is going to be revisited continuously after the research that we have been neglecting for so long gets back under way. Obviously the sooner the better from the standpoint of our capacities to explore deep space.

But you know, I have to remind everybody that we wouldn't have really had the Ares 5 ready to go, according to the Augustine Committee, until the late 2020's in any case. I mean, we were looking at a shortfall in heavy lift capability under the old program, not just under the new.

NASA—VISION

Mr. SCHIFF. Let me ask you a broader question in terms of the vision behind the NASA Human Exploration Program. In particular the moon, while it was somewhere we had gone before was still a goal that caught the imagination of the American people and the plan to get there had goals and time lines. The President has not been explicit about the long-term goal of all the research that is set out, the research and development work that is going to Mars, and that is a serious concern.

Is this plan the faster way to get us to Mars? And if so, why hasn't the President made that case?

Dr. HOLDREN. I think we will be hearing from the President on this. I can't give you a date, but it has been the President's intention to speak up on this topic. As you know he has had his hands pretty full on some other topics, and I think they don't want to put too many out there at once, but we will be hearing from the President on space policy and what his vision is.

Mr. SCHIFF. Well, I think that is really vital. There is a lot of concern here, as you can tell, with the direction of the Space Program and with, you know, the loss—the potential loss of our leadership in this area that has been the source of great pride for the country and innovation and technology, and if there is a good case to be made for why this advances those goals it really will need to be made very forcefully.

I mean, I represent an area that is very heavily involved in robotic exploration——

Dr. HOLDREN. Right.

Mr. SCHIFF [continuing]. And the budget is very kind to robotic exploration, but I also have a great support of the Man Space Program and share the concerns about the degree and length of time in which we will be reliant of the Russians or anyone else for that matter, the degree to which turning our Space Program into an international program will result in—potentially result in delays and loss of American leadership in this area, and I think we would really benefit if we made clearly articulated vision about where our Space Program is going and how this is the best direction to get there.

I mean, I am obviously mindful of the budget realities and have lamented over the last several years that our aspirations and our policies far out stripped our capacity to pay for them, so I have never envied the task of reconciling those two, and I know if you had your way you would have the President focused on this all the time, but he obviously has a lot else on his plate as you mentioned.

I am going to head down, and we probably won't have other members back before this series, so we will recess then until the conclusion of these votes.

Dr. HOLDREN. Good. Thank you.

[Recess.]

Mr. RUPPERSBERGER. Good afternoon.

NASA—CONSTELLATION

Mr. ADERHOLT. Thank you, Dr. Holdren for being here today and for your testimony. And no one envies your job that you have and certainly we all appreciate it, it is a very difficult job that you have and what you are doing.

I would want to mention a little bit about just the overall, and from in recent years the entire discretionary budget requested average just under $1 trillion. President Obama's budget request average over $3 trillion of course that is not counting the stimulus. Our hope was that NASA's request would include realist dollar amounts for human exploration.

The Augustine Commission suggested two to three billion per year for any of the human space flight options to be realistic. The current plan that is before us flushes away $9 billion invested in the Constellation, commits U.S. taxpayer to at least two billion more dollars to shut down these programs, and provides a top line increase of slightly more than $1 billion per year for five years. It terminates the only launch and capsule program which have been guided by NASA's safety criteria to the level of being human rated by NASA. This plan abandons any open of astronauts actually going anywhere beyond the station for at least 20 years.

I am aware of the OMB statement of NASA's mission, I am getting ready to go to Mars, but these science projects should be worked on at the same time as the launch systems like Constellation which will actually get us somewhere.

My first question is regard to the speed that NASA is shutting down the Constellation, even though the commercial options for human space flights are not ready at this point. Fixed costs of launching Ares 1 would be about $1.2 billion a year, any launch system is going to have that high of cost or higher. The marginal costs are costs per rocket would be about 120 million for Ares 1, plus about 50 million for Orion Capsule. The latest estimate for the Completed falcon 9 is about $130 million.

Meanwhile we should note that the original March 2006 contracts NASA sign would the two companies which won COTTS contract called for three demonstration flights by the fall of 2008 showing the ability to deliver cargo to the International Space Station, almost four years later we are still waiting on that first flight.

The transfer of human space flight missions to commercial companies only goes against number one, 2005 and 2008 Space Act bills, 2008 Aerospace Safety Advisory Panel reports, 2009 Aerospace Safety Panel report, and even the Augustine Commission, which I know you referred to earlier, has recommended a back-up launch plan.

The intent of Congress was clearly that NASA would continue these programs until Congress made a decision on the President's proposal.

Isn't it a big risk for our Space Program for NASA to be aggressively canceling and freezing all Constellation contracts which were on schedule to be awarded this year?

Dr. HOLDREN. Well, first of all, Congressman, I believe we are talking about the fiscal year 2011 budget here. This is the President's proposal for what he would like to do in 2011, which obviously is going to be before this Committee and other committees of the Congress.

As I understand it, and I read your letter to the NASA administrator and I read the response from NASA. As I understand it, NASA is not terminating these contracts at this point, it is not in violation of the statute to which you refer here, and it is not NASA's intention, certainly not the Administration's intention, to violate the statute.

We know we need to work with Congress if we are going to execute this change in approach in NASA's Human Space Flight Program and we would plan to do that. There is no intention to violate the law and I don't believe the law is being violated.

Mr. ADERHOLT. So it is your position then that they are not canceling or freezing any of the contracts?

Dr. HOLDREN. My understanding is the understanding embodied in Administrator Bolton's response to your letter. I don't know anything that would contradict that at this point. I must say that contract law and contract management is not my field of expertise——

Mr. ADERHOLT. Uh-huh.

Dr. HOLDREN [continuing]. And so I am relying here on what I read in these materials and what the administrator and his staff tell me, which is that they believe they are in compliance with the law. And the intention is to work with the Congress to implement the change-in-direction for the Human Space Flight Program, putting a heavier emphasis on the development of new technologies, as has been outlined in the Administration's fiscal 2011 budget.

Mr. ADERHOLT. So based on the knowledge you have been given and if they were to ask your advice on it you would advise them not to cancel or freeze any contacts?

Dr. HOLDREN. My advice first of all would be to comply with the law.

NASA—COMMERCIALIZATION OF SPACE EXPLORATION

Mr. ADERHOLT. Yes. Okay. The two Space Act bills passed by Congress in 2005 and 2008 supported some commercial space flight development, but never to the point of eliminating our primary launching capsule plans. NASA has spent $500 million on the COTTS Program. NASA's budget adds another $312 million, which is an additional 60 percent on top of the 500, and then another 500 on top of that in fiscal year 2011 for the commercial crew, and then billions more.

Was there a market study which showed that multiple rocket companies can survive without continued taxpayer support? And can you tell us just how many jobs are created in the first two years and how many jobs are lost?

Dr. HOLDREN. It is my impression that there have been a number of market studies, presumably some of them done by these companies or by their investors about what the prospects for commercial space industry are. I am not personally familiar with those studies, and I can't tell you what particular studies say about the number of jobs. I have seen an estimate that something like 1700 jobs could be associated with the early phase of the growth of a commercial space industry as envisioned in the President's proposal, but again, this is not—I have to tell you, not my domain of expertise. The economic assessment and the jobs assessments, there are other folks who have looked at that much more closely than I have.

Mr. ADERHOLT. So you are not real sure about whether there has been any studies?

Dr. HOLDREN. I am sure there have been market studies. I mean, these folks aren't crazy, they are not investing their own money, as many of them are, without having done some studies to determine that there is a market.

Mr. ADERHOLT. You are just not aware of any that you yourself——

Dr. HOLDREN. But I am not personally—I haven't read those studies, I am not familiar with them in detail.

Mr. ADERHOLT. All right.

Dr. HOLDREN. But I would be happy to get back to you on——

Mr. ADERHOLT. Sure.

Dr. HOLDREN [continuing]. What exists.

Mr. ADERHOLT. If you could that would be very helpful if you could check into that and find out and let me know all about that.

Dr. HOLDREN. Yeah.

Mr. ADERHOLT. Thank you.

Mr. RUPPERSBERGER. I guess we will start another round, so I guess I will start the round. We won't have any votes that is for sure.

NASA—INTELLIGENCE

I asked you when we had a conversation at the White House if you had seen or heard of this report that the Select Committee on Intelligence had done about the Space Program. We've had a lot of failures, and for one year the Technical Tactical Committee of the Intelligence Committee did a year investigation, hearings with all the majors, commercial NRO, the DNI really was our partner, and then we wrote a report, and I assume you haven't seen the report. And the only reason I——

Dr. HOLDREN. This one.

Mr. RUPPERSBERGER. Well you see it now. But why I want to raise this, because—and I said how we were caught by surprise, and a lot of what happens in relationships between administrations and Congress is because a lack of communication and not the right person knowing who where is doing what. But here you have a report that deals on a lot of the issues that you are talking about, more on defense and Intel, but because of the failures we had, and yet the transition team of course would sit down and go over it and most of that information doesn't go where it needs to do.

But you know, I think that that is why when you have people that—like a Committee or an Appropriations Committee that we do NASA's budget, and in Intel you have an authorizing Committee and you do all the research and development.

It is important I think that you or your staff at least read these kind of reports or see if they are out there when you are dealing with Congress, because we really understand the problem I think where you are going, but now the issue is do we agree on how you fix it?

Dr. HOLDREN. Uh-huh.

Mr. RUPPERSBERGER. And again, you started out this hearing about money, we know we have to deal with the issue of money. There is not enough money around to take care of DoD, Intel, and NASA, and NOAA all together, so there has to be some changes.

Your concept clearly of research and development is where we need to go, but don't think Russia and China aren't out there also. I mean last year China graduated 606,000 mathematicians, engineers, and scientists. We are about 66,000.

The good news, and I want to ask you this question, I have been told our curriculum is still superior, but it is not——

Dr. HOLDREN. It is, but the gap is narrower.

Mr. RUPPERSBERGER. The gap is clearly narrowing. And I think the anxiety you hear from my friends on the other side of the aisle too, and I have the same anxiety, when we in fact make a really—a bold move, when we take almost like a drastic move in saying all of a sudden we are going to do away with a lot of these programs, you have a lot of industrial base that have jobs there and a lot of minds that need to be—make sure that they are corrected to other areas. I am just concerned that it is going too quick. We want to do what is best, but I am concerned it is going too quick. I think commercial, as I said before is very positive and we need to do a lot more of it, but you know, I am not sure on how much we can do to get where we need, and if we step back and we allow Russia or China to control the skies I think we have problems.

NASA—SATELLITES

I want to get into two other areas. The one area that I want to discuss is the—and I think this is your field by the way, or you have a lot of say over this, and that is the restrictions on imagery resolutions for commercial satellites.

You know ITAR, and by the way in this report we talk about ITAR, how we before ITAR we controlled 73 percent of the space industry, we are at 27 percent now, and it is slipping, and we got it passed in the House, now we have to get something done in the Senate, and hopefully we can do something with respect to ITAR. But I see the same analogy here that we are so restrictive on imagery resolution for commercial satellites. And France, Germany, Spain, and Italy are all building satellites that have current resolution capabilities that we can't do it because we won't let our people. And I would hope that you would look at this so that we can be competitive.

Congress passes way too many laws, and a lot of these laws have unintended consequences, and I think this is exactly what happened in ITAR, and I think it is happening here.

So could you give me a commitment that you will evaluate our restrictions on imagery resolutions for commercial satellites?

Dr. HOLDREN. Absolutely.

Mr. RUPPERSBERGER. Have you looked at it already?

Dr. HOLDREN. Absolutely. We have started to look at that. The Administration is looking very carefully at the whole ITAR and the larger export restrictions domain. We know we have problems there, and my own view is that it is possible to make some considerable improvements that will benefit both our security and our economy.

Mr. RUPPERSBERGER. And of course you have to balance the security. But you know, ITAR has taken ten years just to get something out of the House, and we did it in a bipartisan way, now the Senate is sitting on it.

Dr. HOLDREN. I mean, you know——

Mr. RUPPERSBERGER. We need the Administration to step up for ITAR right now.

Dr. HOLDREN. And I think you are going to see that.

But on the specific question you raise about the resolution of commercial imagery, yes, we are looking at that. We know there is an active global market in imagery, we monitor those developments closely, we understand their issues related to what our government will allow that are problematic in that domain, and we expect to be reviewing and updating the Administration's position on that.

Mr. RUPPERSBERGER. And that is probably going to be soon?

Dr. HOLDREN. Yes. I have no problem giving you the assurance you want, Congressman, that yes, we are looking at it, we will be looking at it, and sooner rather than later. We are already looking at it.

Mr. RUPPERSBERGER. Okay. The other issue is weather satellites. Now we know probably you need usually one boss, that is a problem when we had the DoD and I think——

Dr. HOLDREN. NASA, NOAA, and DoD.

Mr. RUPPERSBERGER. You know, not any real boss and you need one boss, you need a plan, whatever, I mean that is just basic management. And then I think you all made a decision to give the weather satellites over to NOAA and then they canceled the satellites. And even though we know we have two satellites in the barn, so to speak, they are older satellites.

But my concern about the cancellation of the satellites, again, something happening rather quickly, there is a lot of research and development and there is a lot of technology that exists right now that is almost ready to go, because this project has been out there for a while, and with NOAA coming in and saying well we are canceling the project that we were working on, that I am afraid we are going to lose millions, if not billions of dollars, a lot of research and development that has been there, and it is a move that I am concerned about.

Dr. HOLDREN. We are not canceling things there. We are splitting the responsibility for acquisition between the morning and the afternoon orbits in these polar orbiting environmental satellite systems so that the DoD is responsible for acquisition for the morning orbit, and NASA and NOAA responsible for acquisition for the afternoon orbit, but we are not terminating the work that has been going on on the instruments, we are not losing that investment. Those instruments are going to fly, they are going to continue coordination of the data streams and the ground station.

A lot of the problems with that program have been in the acquisition stage, and we think we've got an approach——

Mr. RUPPERSBERGER. By the way, that falls to space too, is that true?

Dr. HOLDREN. Yeah, yeah.

Mr. RUPPERSBERGER. Sorry.

Dr. HOLDREN. We think we've got an improved approach to that. It is a tough problem in which one is looking in a way for the least bad solution because there is no ideal one. They all have some liabilities, but we are certainly not terminating these capabilities, we are not terminating the instruments. We are going to finish those instruments, we are going to fly them.

Mr. RUPPERSBERGER. In preparation for this hearing today we just got this information, but I would like to know what is our plan for future satellites? Are we going to rely on your opinions more? Where are we going? The two that we have in the barn are I believe rather old, I mean they don't work at least.

Dr. HOLDREN. Well those are the ones that DoD has in the barn.

Mr. RUPPERSBERGER. Right, okay. Now where is our plan for weather satellites? Do you have a plan for that down the road?

Dr. HOLDREN. Well in short yes, we do have a plan for weather satellites. And again, the origin of this program was the realization that the needs of the DoD and the needs of NOAA in terms of weather satellites overlap quite a lot, and the theory was that since these needs overlap so much why not combine them into a single joint operation which would meet the needs of the civil sector and the military sector at the same time? Now that turned out in practice to be a lot harder to execute I think than anybody imagined when it was thought up in the '90s, in part because of the different acquisition models of these agencies, their different degrees of risk tolerance, and differences in their missions——

Mr. RUPPERSBERGER. Uh-huh.

Dr. HOLDREN [continuing]. Which were greater I think than folks were imagining when they put this together.

But the fact that we are separating now part of these particular missions doesn't have any implication for conceding leadership in weather satellites and earth observation satellites to other countries.

We are for these particular polar orbiting satellites relying on the Europeans for what's called the mid-morning orbit. We have been for a long time, we will continue to do that because they are making the observations and making the data available that we need. But you know, we have a robust program of weather and climate monitoring satellites and we are going to keep one.

Mr. RUPPERSBERGER. Okay. Okay, who is—Frank are you next?

Mr. WOLF. Sure. Thank you, Mr. Chairman.

I don't think I am going to ask really many questions, but I think there is a degree of secrecy or urgency that has been connected with this decision.

I just saw this press release here and it says, "Attorney General Eric Holder didn't consult the Department of Homeland Security before he made plans to try alleged September 11 mastermind Khalid Sheikh Mohammed in New York city, Homeland Security Secretary," Janet Napolitano said Wednesday.

I think the same thing is really happening here. I voted against the stimulus package, but there were some members, and I thought it made some sense that asked the Administration, particularly with some of the funding that went into areas that then create jobs to have taken some money out of the stimulus. I believe there were some members of Congress, I don't know how many, that sent a letter down. Perhaps some voted for the stimulus, perhaps didn't vote for the stimulus, and I know that the Administration has been critical of people who—and I have gone to for ribbon cuttings for any stimulus money because I didn't vote for it, and I would never go to a ribbon cutting. But there apparently were a number that said you ought to consider it.

NASA VISION

Secondly there is really a concern that there really isn't a goal, there really isn't a vision, there isn't anything that kind of captures your imagination the way that President Kennedy did about putting a man on the Moon.

I have a whole series of questions that I will submit, but it doesn't appear to me that you really have a goal. It doesn't appear to me that you have a vision that you can capture. And you were talking as I came in about the STEM grants. You know, 50 percent of the STEM funding last year as laid on the table was not accessed. We are losing the young people because there is not that imagination, that interest, and everything else. We used to be number one on all these test scores and now we are dropping, we are dropping, we are dropping.

And I think before you do anything, I am going to oppose what you are trying to do. I have talked to Dr. Griffin, I have talked to a number of other people, some just call me out of the blue. To me I think it is an abdication of America's leadership. The thought of having to abdicate leadership to the Chinese, and your viewpoint on China and mine are totally different. The President wouldn't meet with the Dali Lama, similar to President Ford, wouldn't meet with Solzenitzen, and you know, but to have the Chinese impact us that way, and I think what this means is they are probably laughing about this in Beijing.

But I think you needed a public aspect, you needed to bring some of the best minds together. Iron sharpens iron. Bring them together to have a public discussion as to where we go. I am not going to say everything you have said is right, or everything you said is wrong, but it was sort of a surprising decision, and the NASA people have called me.

One of the interesting things about my district, my district is Northern Virginia out into the Shenandoah Valley. When the Administration was going to secretly move terrorists from Guantanamo Bay and put them in Northern Virginia I had asked Eric Holder about it, they refused. Finally people from different agencies, three different agencies called and told me today the Administration are moving the people. So a lot of the people that work in NASA and even some that maybe work right where you are, live in my district, some go to my church, so everyone that is called felt that this was done in a very, very poor way. And so whatever you do you need to bring people together of all different viewpoints.

I stipulate you certainly are not a bad person. I mean, I don't think that you are trying to destroy the program, but bring everyone in together—and you didn't do that—and as a result of that there isn't any plan, there aren't any ideas, and your people are becoming demoralized. I talked to a person the other day who was down at the space shuttle launch and they said the administrator in NASA told the people, and now you have done a great job, you won't be around next year because you are all going to be gone, but you have really done a great job. That's, demoralizing. Here you got a person who has been with NASA, dedicated, working the hours that they work, done what they have done, maybe have one kid in college, another kid, you know, getting ready to go into college and you just tell them you are out, you are gone.

Now this isn't a jobs issue for me. I don't represent Alabama, I don't represent Texas, I don't represent Florida. I represent the Northern Virginia area, and so I just think the way you have gone about it has a degree of arrogance, and I think you are going to have a problem.

I am going to do everything I can to stop this and to see if there is a way to kind of look at this thing in a different way.

With regard to that I am not going to ask you other questions.

Mr. RUPPERSBERGER. John. John.

NASA VISION

Mr. ABNEY. Yeah. Thank you, Mr. Chairman. I as a Houstonian do not physically represent NASA, and my passion and support for the Space Program stems out of a personal passion for the sciences. I have been an amateur astronomer, was a nerd in high school, bought myself a telescope when I graduated from high school, great passion about my support for the sciences, medical scientific research, and NASA for the technological benefits, but as Mr. Wolf has just so eloquently said, NASA sparks vision and hope and inspiration in young people where no other government agency can. It is probably the only federal function other than our military, God bless them, the young men and women that go into the Armed Forces have a great deal of zeal in their hearts and excitement for the mission that they have and it inspires a lot of young people to go in the military, the work that our men in uniform do.

NASA inspires young people to go into the sciences and mathematics, and to engineering and is the one agency frankly among all of the federal government that has a highest level of public approval, support, and it is a fact no matter what you, you know, said or how you couch it in terms of you consulted with NASA administrators or with the center directors about options. The center directors were not told in advance that the Administration's number one consideration was to cancel Constellation. It was done very poorly as Mr. Wolf says, and these are wonderful good people who I honestly—I don't have—I have got maybe a few jobs in my district from NASA, I am on the far west side of Houston, and this is really a personal passion for me. I feel as the members of this Committee do that our investment in the sciences and NASA is a viable part of our strategic.

I support strongly what Mr. Ruppersberger does in his committee, and how important those intelligent assets are in orbit, how critical it is that we preserve that lower orbit capability at an absolute minimum, and if the Administration were, Dr. Holdren, to succeed in canceling the Constellation Program, what space vehicle as we sit here today is capable of carrying humans into space and how soon?

Dr. HOLDREN. Well first of all, Congressman, let me clarify a couple of things. The first is I too was a nerd. I have two MIT degrees in aeronautics and astronautics, my senior class project at MIT, which I loved, was to design a man to Mars mission, and we did it. Class of 1965, 300 pages. And so I understand everything you are saying about the importance of NASA, its inspirational effect.

I was one of the kids who was inspired by the need to respond to Sputnik in 1957, I was at the beginning of my high school years at that time, and so I completely relate to that set of views.

Nothing about what we are doing is intended to run down NASA, to retreat from U.S. leadership in space. I understand we have a disagreement about the right way to do it, but you need to understand first of all that we think we have an approach that will help NASA inspire again.

I don't know if you knew about the event last October 7th, Astronomy for Kids on the White House lawn——

Mr. ABNEY. But your intention is not what's at issue here. The point is what the effect of what you are doing is you have—you are proposing to cancel the Manned Space Program. There is no other way to look at that. If you cancel Constellation the only man ready rocket in the U.S. inventory today is Ares, it just was tested, it will be land ready very soon, that is the one rocket we've got. Burt Rutan, who is opposed to what you are doing, succeeded in doing this, only as Alan Shepard did. He just went up and down very quickly. So——

NASA—MANNED SPACE PROGRAM

Dr. HOLDREN. I understand that, but——

Mr. CULBERSON. And other than Ares what other rocket——

Dr. HOLDREN. Ares——

Mr. CULBERSON. Please answer my question. Other than Ares, what rocket as we sit here today is ready within how many years to carry humans into orbit?

Dr. HOLDREN. First of all Ares is not ready. Ares would not be ready until 2017 or 2018 in the judgment of the Augustine Committee.

Mr. CULBERSON. I am not asking about that.

Dr. HOLDREN. Well the point is it is not right to say "well, we have Ares" as a bird in the hand and you are only offering birds in the bush. Ares is out there too. Ares is 2017 or 2018 if everything goes well.

Mr. CULBERSON. It has been tested successfully and it is already on path and we've spent $3 billion dollars, Mr. Ruppersberger, I know we all on this Committee we spent $3 billion getting that rocket ready and it is on track, it is over budget, and it is a little behind schedule, these things are complicated. But other than Ares, if we take Ares as you propose to do, you cancel Ares, what rocket as we sit here today is ready to carry humans into space and how soon?

Mr. HOLDREN. None are ready to carry humans into space today. No U.S. rocket is ready to do that today.

Dr. CULBERSON. So which one as you sit here today will be ready?

Dr. HOLDREN. On that time scale we could have a Space X rocket, we could have a Boeing rocket, we could have a man rated Delta 4, we could have a man rated Atlas 5. The short answer is I don't know which one is going to succeed.

One of the merits of the American system is when you turn the private sector loose and say we have got this task and you are going to get to compete for success, we will have a success.

Mr. CULBERSON. And I got a little excited last time because this upsets me, this upsets me a lot. But there it is, gentlemen, it is speculative. There is no rocket ready to take the place of Ares. The gap is going to be five years. I wish there were no gap. And I was appalled when the Bush Administration's vision turned out to be a press release and they didn't give this Committee the money we needed, and we know it, you know how it came about. It was infuriating and it under funded NASA, short all those wonderful employees with mortgages as Mr. Wolf so correctly pointed out. I mean you have got kids in college, you have mortgages, you have worked your heart out designing a new rocket and you were just told a month ago by the new administrator we are behind you, the Administration is behind you, Constellation is full speed ahead, and then two days before the announcement it is canceled.

Can you imagine how that rips their heart out of their chest? What you have done to those wonderful people, those engineers, God bless them, and scientists and astronauts. Set those jobs aside, those are vitally important jobs that are important for America's future, but we have no other rocket members of the Committee. There is no other rocket ready. There is not even one on the horizon, it is all speculative. The one rocket we have that is being tested and is over budget and behind schedule is Ares, which you are proposing to cancel.

Dr. HOLDREN. It is way over budget and it is way behind schedule and we think there are other options.

Mr. CULBERSON. But you don't even know what that would be. And we can't afford a gap, we can't afford a gap of one year much less five years, and then what are you going to do with the gap?

NASA—CHINA

Let me ask also something I know was mentioned by Mr. Ruppersberger, I heard you say earlier that the Chinese might help us get to the International Space Station. And I just read an article, members, that Mr. Ruppersberger I know as a member of the Intelligence Committee read, probably the same alarm that I did, that the Administration is considering inviting the Chinese to come participate and help us in our Space Program? Now that has never been done, because the Chinese space program is a military space program whose primary purpose is designed how to better target their ICBMs on American cities and take out our satellites. So I am very concerned.

Would you please tell the Committee what the Administration is doing to expand the cooperation of the Chinese in our Space Program, since they have never been allowed before any where near our facility?

Dr. HOLDREN. I don't think there are any plans that I know of. The only thing I know of is that Administrator Bolden did go to China, and about the same time the President went to China, he certainly had some conversations with leaders of the Chinese space program about areas of potential cooperation. There were no agreements reached. This was a very exploratory discussion. I wasn't there.

Mr. CULBERSON. Well certainly for me I know and the members this Committee——

Mr. RUPPERSBERGER. John, It is already happening. The Chinese have cyber attacked NASA on a regular basis.

Mr. CULBERSON. They do and recollects it is a real concern.

Mr. RUPPERSBERGER. Not that we let them do it.

Mr. CULBERSON. Right. It is a real concern that I share with my good friend Mr. Ruppersberger from Maryland that Chinese are not our friends and particularly when it comes to space, and they are using that technology to better target their ICBMs and take out our satellites. The high ground today is low earth orbit in outer space.

And again, it is just not acceptable to me or this Committee, I am quite confident that we are going to surrender the high ground of outer space.

Dr. HOLDREN. We are not going to surrender it, sir.

Dr. CULBERSON. You have already surrendered it, sir. You are proposing to cancel Constellation and you just testified there is no rocket ready to replace Ares.

Mr. HOLDREN. That doesn't amount to surrendering space. We have huge capacities in space.

Mr. CULBERSON. Okay.

Dr. HOLDREN. And we have them in the military sector and in the civil sector, and we are not going to surrender our leadership.

Mr. CULBERSON. And I would like to hear from Mr. Wolf.

Mr. WOLF. The arrogant facial expressions of your staff behind you is unbelievable. You particularly, you. I mean, I don't care who you work for, but the arrogance of it I have some pretty tough questions, I am not going to ask them. You too. I wish I had a camera taking your facial expressions. I think you really bring a degree of arrogance here that it is just offensive. I yield back.

Mr. RUPPERSBERGER. Okay, my turn. One of the issues that I think that we are dealing with here today is we don't have enough information, it came too quick. You know, those of us who work a lot in this area just did not—we were just surprised where we are going, but we want a road map and we want a plan and then we want it justified.

I think some of the things about this program, and let me try to—and some of this is classified so I won't get into it. You know the major program that was canceled about three or four years ago, it was one of the majors, it was one of our big satellite programs over budget and whatever, and what happened, why that was canceled is because it was way over cost, over budget, and it got to the point you keep putting more money into it what are you going to get out of it number one? And you know, some of the things that we wanted to get out of that program weren't going to happen, so we had to re-evaluate because there was only a certain amount of money.

Now I assume as you talk about Ares, there is Ares 1, but then there is the one we are focusing on now that John is focusing on or whatever. And it is my understanding that the cost of that, if you move forward the way it is now are in the billions and billions, and that we still—it might be a black hole that we are not sure if we can produce.

Wait one second, I will get you. But is that where you are coming from on your focus on Ares? I mean, changing——

Dr. HOLDREN. Well that is certainly an important part of it. Ares which originally was expected to cost four and a half billion dollars is now expected to cost something like 18.

Mr. RUPPERSBERGER. Right, okay. I didn't know if that was classified, whatever, it probably isn't, okay. But go ahead, John, yeah.

Mr. ABNEY. Very quickly if I could.

Mr. RUPPERSBERGER. Okay.

Mr. ABNEY. The reason the cost gets so high is because you are trying to go to Moon and Mars, and my focus here is I think we need as a Committee to stay focused on we have got to preserve the ability to go to lower earth orbit. That is far less expensive and far more doable.

Mr. RUPPERSBERGER. I would think that we are there more on the lower orbit, I think the major concern with the Space Program though, if you were involved with Sputnik, the reason we are as good as we are now is because we responded to Sputnik and we actually created rocket science as people who research and development. And all that we did to get to the Moon helped us dominate where we are now and we are losing that dominance, and that is where I am sure—I applaud you for evaluating where we are and what we are doing, I am just worried that we don't have enough and that we are not sure. And we want to work with you, because it is all end game in the end. What's right for our country, our national security. And I will work with you, but you know, you have got to work with us.

Dr. HOLDREN. Oh, we will, and we want to get the leadership back.

Mr. RUPPERSBERGER. We need a lot more information. You know, Augustine has one report. There are people on both sides. And I tell you, I haven't been sold yet today, myself. I am willing to work with you, but I mean, I just want to get some experts and hear these different points of view before I decide where to vote—you know, what to do with this program.

And again, I am worried we are going way too quick when you are dealing with the national security that is at stake. Because if it is the wrong decision then we could really put ourselves in a real bad position. We need to be dominant in space.

One thing about it, do you have launch? Is that in your capacity too, the launch issue, launching? The ability to get the satellites up?

Dr. HOLDREN. Well, I mean in the Office of Science and Technology policy we are responsible for advising the President on every aspect of science and technology that affect——

Mr. RUPPERSBERGER. I would like you to look at it, because in my opinion——

Dr. HOLDREN [continuing]. His positions.

Mr. RUPPERSBERGER [continuing]. We are behind France in launch and maybe another country too, and whenever I hear the United States is behind and for a lot of different reasons, but you know, there is a consortium with one group, you have other issues, there are certain satellites that should have gone up by now that were canceled because we couldn't deal with it. I really hope you focus on the issue of launch, because it bothers me when the United States is not number one in that arena.

John. Frank.

Mr. WOLF. No, I am fine.

Mr. RUPPERSBERGER. Is that it, all the members? Okay, well thank you for being here. I think if anything we learned today it is the issue of communication.

Dr. HOLDREN. Yeah, I agree.

Mr. RUPPERSBERGER. And you know, we have got to get some of our people to advise us and whatever of pulling that together, because it is a really big issue.

Dr. HOLDREN. We will try to do better with that.

Mr. RUPPERSBERGER. I really understand the cost. You know, DoD, Intel, NASA all together, we don't have enough money for everyone. Okay.

Dr. HOLDREN. Thank you, sir. Appreciate it.

Mr. RUPPERSBERGER. Meeting adjourned.

<u>Chairman Alan Mollohan</u>
Questions for the Record

The American Recovery and Reinvestment Act added over $18 billion in funding for R&D across many agencies.

1. **Overall, how much of this money has been committed and how much has been spent?**

   Answer: As of April 2010, approximately $12.6 billion (or 69 percent) has been obligated and $2.3 billion (or 13 percent) has been spent. The Recovery Act provided $18.2 billion in R&D funds across several Federal agencies, as documented in R&D funding data released with the President's 2011 Budget. Although there is not a one-to-one match between R&D funding and specific agency programs, the following table shows data for $18.4 billion in Recovery Act appropriations for key programs that make up nearly all of the $18.2 billion Recovery Act R&D investment:

   [The table follows:]

Table. Recovery Act obligations and outlays for R&D programs as of April 2010

Program	ARRA approp	obligated	spent
DOE Office of Science	$ 1,633,000,000	$ 1,626,550,383	$ 327,049,512
DOE ARPA-E	$ 389,000,000	$ 166,562,651	$ 5,067,764
NSF Research & Related Acts.	$ 2,500,000,000	$ 2,207,993,015	$ 230,438,256
NSF MREFC	$ 400,000,000	$ 400,000,000	$ 7,411,078
National Institutes of Health	$ 10,400,000,000	$ 6,364,037,991	$ 1,361,369,591
Agency for Healthcare Res.	$ 700,000,000	$ 65,971,845	$ 8,070,323
DOD Army	$ 75,000,000	$ 70,013,924	$ 2,716,642
DOD Navy	$ 75,000,000	$ 69,262,069	$ 33,497,150
DOD Air Force	$ 75,000,000	$ 10,024,859	$ 7,814,794
DOD Defense Wide	$ 75,000,000	$ 60,912,184	$ 4,493,640
USDA Agricultural Res. Service	$ 176,000,000	$ 40,749,449	$ 5,084,402
U.S. Geological Survey	$ 140,000,000	$ 100,689,177	$ 19,279,843
NIST Scientific and Tech. Res.	$ 220,000,000	$ 129,638,628	$ 22,676,767
NIST Construction of Facilities	$ 360,000,000	$ 259,602,842	$ 9,068,720
NOAA Operations, Res., Facils.	$ 230,000,000	$ 214,019,313	$ 61,330,197
NASA Science	$ 400,000,000	$ 325,319,829	$ 180,678,537
NASA Exploration	$ 400,000,000	$ 381,429,202	$ 60,385,169
NASA Aeronautics	$ 150,000,000	$ 110,929,293	$ 2,037,241
TOTAL	$ 18,398,000,000	$ 12,603,706,654	$ 2,348,469,626

www.recovery.gov

OSTP April 2010

2. **How many jobs have resulted?**

   Answer: Because recipient reports of jobs created or retained are lagging behind Recovery Act awards, the availability of jobs data is limited at this time. But early data are promising. National Science Foundation recipients of Recovery Act funds, for example, report 2,507 full-time equivalent jobs created or retained with NSF Recovery Act funds in FY 2009 (between February 17 and September 30, 2009) and 2,897 in the first quarter of FY 2010. NASA Recovery Act recipients report 1186.3 full-time equivalent jobs from NASA Recovery Act funds in the first quarter of FY 2010, up from 836.7 jobs funded in FY 2009 (between February 17 and September 30, 2009). Trans-NIH Recovery Act funding resulted in 5,445.8 full-time equivalent jobs created or retained in FY 2009 (between February 17 and September 30, 2009) and 12,031.1 jobs created or retained in the first quarter of FY 2010. More complete jobs data will be available after second-quarter FY 2010 reports are filed (after March 31). All jobs data are available at www.recovery.gov.

3. **How many scholarships and fellowships have been awarded, and at what levels and in what fields?**

   Answer: There is no comprehensive inventory of scholarships and fellowships awarded under the Recovery Act. In part, this is because science and engineering (S&E) scholarships and fellowships are often funded as part of research grants rather than as separate awards. But the Recovery Act is already having dramatic impacts on students' opportunities to pursue science and engineering careers. NIH, for example, expects to support 659 full-time training positions (FTTPs) with Recovery Act funds through the Ruth L. Kirschstein Training Awards program. NSF estimates that 15,945 graduate students, 7,868 undergraduate students, and 1,945 postdoctorates will be supported in whole or in part by Recovery Act funds through a mix of separate awards and support through research projects or centers.

Overall funding for STEM education at NSF is only increased by 2.3%, and at NASA, funding for astrophysics and heliospheric physics is virtually frozen.

4. **What is the rationale for the lack of a 7% or greater increase in STEM education funding at NSF?**

   Answer: The 2011 Budget proposes a substantial increase for NSF STEM education programs within a nonsecurity discretionary budget that is flat with 2010 enacted funding levels. The 2011 Budget proposes a 4.7 percent increase for STEM programs across NSF, as counted within NSF's "learning" strategic plan goal. A 4.7 percent increase is substantial compared to overall growth in nonsecurity discretionary programs in the Budget. The fact that the total NSF budget increases at 8.0 percent is indicative of the President's strong support for basic research as a key element for long-term economic growth. There are other ways of measuring NSF STEM education funding. The 2.3 percent increase applies to NSF STEM programs from a government-wide inventory of separately identified STEM programs, which does not include STEM education efforts incorporated into primarily research-oriented programs; a 2.2 percent increase applies only to NSF's Education and Human Resources Directorate, which accounts for most but not all of NSF's STEM education funding.

[The tables and chart follow:]

National Science Foundation
By Account and Strategic Outcome Goal
FY 2011 Request to Congress
(Dollars in Millions)

NSF Accounts	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request: Discovery	Learning	Research Infrastructure	Stewardship	FY 2011 Request	Change over FY 2009 Omnibus Actual: Amount	Percent	Change over FY 2010 Estimate: Amount	Percent
FY 2009 Omnibus Actual	**$6,468.76**	**$2,401.66**		**$3,448.63**	**$905.12**	**$1,703.57**	**$411.44**					
FY 2010 Estimate			**$6,872.51**	**$3,813.20**	**$967.38**	**$1,662.18**	**$429.75**					
BIO	$656.62	$260.00	$714.54	$577.84	$52.45	$123.23	$14.29	$767.81	$111.19	16.9%	$53.27	7.5%
CISE	574.50	235.00	618.83	600.87	38.84	30.60	14.20	684.51	110.01	19.1%	65.68	10.6%
ENG	664.99	264.99	743.93	703.36	73.99	33.33	14.99	825.67	160.68	24.2%	81.74	11.0%
ENG Programs	*574.60*	*215.08*	*618.16*	*560.50*	*73.99*	*33.33*	*14.99*	*682.81*	*108.21*	*18.8%*	*64.65*	*10.5%*
SBIR/STTR	*90.39*	*49.91*	*125.77*	*142.86*	-	-	-	*142.86*	*52.47*	*58.0%*	*17.09*	*13.6%*
GEO	808.53	347.00	889.64	504.35	45.50	387.60	17.84	955.29	146.76	18.2%	65.65	7.4%
MPS	1,243.88	474.97	1,351.84	972.35	65.01	349.10	23.45	1,409.91	166.03	13.3%	58.07	4.3%
SBE	240.56	84.97	255.25	201.00	15.67	46.36	5.76	268.79	28.23	11.7%	13.54	5.3%
OCI	199.23	80.00	214.28	73.12	11.21	138.66	5.08	228.07	28.84	14.5%	13.79	6.4%
OISE	47.45	13.98	47.83	38.77	12.83	0.10	1.56	53.26	5.81	12.2%	5.43	11.4%
OPP[1]	473.55	171.89	451.16	123.96	6.99	391.15	5.89	527.99	54.44	11.5%	76.83	17.0%
IA	241.58	129.85	275.04	179.80	21.83	93.04	1.26	295.93	54.35	22.5%	20.89	7.6%
U.S. Arctic Research Commission	1.50	-	1.58	1.60	-	-	-	1.60	0.10	6.7%	0.02	1.3%
Research & Related Activities	**$5,152.39**	**$2,062.64**	**$5,563.92**	**$3,977.02**	**$344.32**	**$1,593.17**	**$104.32**	**$6,018.83**	**$866.44**	**16.8%**	**$454.91**	**8.2%**
Education & Human Resources	**$845.52**	**$85.00**	**$872.76**	**$191.44**	**$668.73**	**$15.71**	**$16.12**	**$892.00**	**$46.48**	**5.5%**	**$19.24**	**2.2%**
Major Research Equipment & Facilities Construction	**$160.76**	**$254.00**	**$117.29**	-	-	**$165.19**	-	**$165.19**	**$4.43**	**2.8%**	**$47.90**	**40.8%**
Agency Operations & Award Management	**$294.09**	-	**$300.00**	-	-	-	**$329.19**	**$329.19**	**$35.10**	**11.9%**	**$29.19**	**9.7%**
National Science Board	**$4.02**	-	**$4.54**	-	-	-	**$4.84**	**$4.84**	**$0.82**	**20.3%**	**$0.30**	**6.6%**
Office of Inspector General	**$11.99**	**$0.02**	**$14.00**	-	-	-	**$14.35**	**$14.35**	**$2.36**	**19.7%**	**$0.35**	**2.5%**
Total, National Science Foundation	**$6,468.76**	**$2,401.66**	**$6,872.51**	**$4,168.46**	**$1,013.05**	**$1,774.07**	**$468.82**	**$7,424.40**	**$955.64**	**14.8%**	**$551.89**	**8.0%**
Percent Increase over Prior Year				9.3%	4.7%	6.7%	9.1%					
H-1B Visa	*$89.08*		*$100.00*					*$100.00*				
Reimbursables	*119.27*											
Trust Fund	*56.81*											
Total NSF, Including H-1B Visa, Reimbursables & Trust Fund	*$6,733.92*	*$2,401.66*	*$6,972.51*	*$4,168.55*	*$1,013.10*	*$1,774.14*	*$468.91*	*$7,524.40*	*$790.48*	*11.7%*	*$551.89*	*7.9%*

Totals may not add due to rounding.
[1] Funding for FY 2010 excludes a one-time appropriation transfer of $54.0 million to U.S. Coast Guard per P.L. 111-117.

National Science Foundation
Learning Funding by Level of Education
FY 2011 Request to Congress

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request	FY 2011 Request change over: FY 2009 Omnibus Actual Amount	Percent	FY 2010 Estimate Amount	Percent
K-12 Programs	$60.07	$25.00	$57.17	$57.06	-$3.01	-5.0%	-$0.11	-0.2%
Undergraduate Programs	266.07	85.51	288.60	291.07	25.00	9.4%	2.47	0.9%
Graduate & Professional Programs	328.32	119.84	366.72	379.36	51.04	15.5%	12.64	3.4%
Multi-level and Other Programs	250.67	19.02	254.89	285.56	34.89	13.9%	30.67	12.0%
TOTAL, NSF	**$905.12**	**$249.37**	**$967.38**	**$1,013.05**	**$107.93**	**11.9%**	**$45.67**	**4.7%**

	FY 2009 Enacted	ARRA	FY 2010 President's Budget	2010 Enacted	2011 PB	2011 PB vs 2010 Enacted
Advanced Technological Education (ATE)	52	0	64	64	64	0
Alliances for Graduate Education and the Professoriate (AGEP)	17	0	17	17	17	0
Broadening Participation in Computing (BPC)	14	0	14	14	14	0
Centers for Ocean Science Education Excellence (COSEE)	5	2	6	6	5	0
CISE Pathways to Revitalized Undergraduate Computing Education (CPATH)	5	0	5	5	5	0
Climate Change Education (CCE)	10	0	0	10	10	0
Comprehensive Broadening Participation of Undergraduates in STEM	0	0	0	0	103	103
Cyberinfrastructure Training, Education, Advancement, and Mentoring for Ou	0	0	7	5	5	0
Discovery Research K-12 (DR-K12)	108	0	109	119	119	0
Engineering Education (EE)	5	18	13	13	13	0
Enhancing the Mathematical Sciences Workforce of the 21st Century (EMSW2	14	13	17	17	16	-1
Excellence Awards in Science and Engineering (EASE)	5	0	5	5	5	0
Federal Cyber Service: Scholarship for Service/Cybercorps (SFS)	15	0	15	15	15	0
Geoscience Teacher Training (GEO-Teach)	3	0	3	3	2	-1
Graduate Research Fellowships (GRF)	115	47	122	136	158	22
Graduate Teaching Fellows in K-12 Education (GK-12)	56	3	54	54	53	-1
Historically Black Colleges and Universities Undergraduate Program (HBCU-UP	31	0	32	32	0	-32
Informal Science Education (ISE)	66	0	66	66	64	-2
Innovative Technology Experiences for Students and Teachers (ITEST)	28	0	25	25	25	0
Integrative Graduate Education and Research Traineeship Program (IGERT)	64	14	69	69	62	-7
Interdisciplinary Training for Undergraduates in Biological and Mathematical S	3	0	3	3	3	0
Louis Stokes Alliances for Minority Participation (LSAMP)	43	0	45	45	0	-45
Math and Science Partnership (MSP)	61	25	58	58	58	0
Opportunities for Enhancement of Diversity in the Geosciences (OEDG)	5	7	5	5	4	-1
Post-Doctoral Fellowship Programs (PFP)	12	20	20	20	22	2
Professional Science Masters Program (SMP)	0	15	0	0	0	0

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	FY 2009 Enacted	ARRA	FY 2010 President's Budget	2010 Enacted	2011 PB	2011 PB vs 2010 Enacted
Research and Evaluation on Education in Science and Engineering (REESE)	43	0	43	46	46	0
Research Experiences for Undergraduates (REU) Sites	50	25	51	50	51	1
Research in Disabilities Education (RDE)	7	0	7	7	7	0
Research on Gender in Science and Engineering (GSE)	11	0	12	12	11	-1
Robert Noyce Scholarship Program (NOYCE)	55	60	55	55	55	0
Scholarships in Science, Technology, Engineering and Mathematics (S-STEM)	61	0	75	75	75	0
STEM Talent Expansion Program (STEP)	29	0	33	33	33	0
Transforming Undergrad Education in STEM (TUES; formerly CCLI)	41	0	40	42	41	-2
Transforming Undergraduate Biology Education (TUBE)	1	0		11	16	5
Tribal Colleges and Universities Program (TCUP)	13	0	13	13	0	-13
Undergraduate Research Collaboratives (URC)	2	0	1	1	0	-1
Undergraduate Research Mentoring in the Biology (URM)	3	2	5	3	3	0
Total for National Science Foundation	**1,054**	**250**	**1,107**	**1,151**	**1,177**	**26**
Grand Total	**3,613**	**339**	**3,680**	**3,681**	**3,708**	**27**

5. **Aren't astrophysics and heliospheric physics at NASA deserving of increases similar to those accorded most science disciplines at NSF?**

   Answer: The National Academy of Sciences is currently finishing a decadal review of astronomy and astrophysics. This review is expected to be complete in September, in time to impact the FY12 budget request. The FY11 request for these areas reflects the fact that NASA, NSF, and OSTP are waiting on these community recommendations before setting priorities for new projects. The National Academy of Sciences will follow with new decadal surveys in Planetary Science in 2011 and Heliophysics in 2012.

Although it took too long, I want to thank OSTP for its work to put development of the next generation of polar orbiting operational environmental satellites on a sound management and financial basis. NOAA and NASA are clearly moving forward with their responsibilities for the afternoon orbit.

6. **What are the Defense Department plans for the morning-orbit?**

   Answer: DOD is working on a short study of their needs for weather observations in the morning orbit, in order to determine whether they want the improved capabilities that NPOESS would have provided, or if they will be satisfied with the "legacy" capabilities that are similar to their current polar-orbiting satellite system (DMSP). We expect a decision from DOD in the near future about what their architecture will be to support their requirements. While this study is being conducted, DOD will fully support NOAA's needs to ensure continuity of data in the afternoon orbit by transitioning appropriate and relevant activities from the current NPOESS effort.

7. **Given the mutual use of data by NOAA and DOD and their shared responsibilities for termination liabilities, don't DOD decisions still have the potential to increase NOAA costs?**

   Answer: Yes, the agencies' finances in FY2010 and FY2011 are still intertwined as they determine their respective ways ahead in their assigned orbits. The DOD decisions on the architecture for the early morning orbit (specifically whether or not to continue work on the NPOESS portions of the contract such as the spacecraft bus) could impact any potential termination liability. NOAA's decisions on whether or not to use the NPOESS spacecraft bus for the afternoon orbit have a similar impact. The agencies are taking this issue into account as they move forward with their decision process. The agencies are currently in negotiations with Northrop-Grumman, and the contractor has agreed to be supportive during this transition. There is the potential for some termination costs, and these will be split 50-50 between NOAA and DOD. We will know more about the details of this in the near future.

Additionally, NOAA is solely responsible for the ground system which will provide operations and data handling for both the early morning and afternoon orbits. DOD's architectural decisions could have cost implications for the ground system algorithms, ground system architecture as well as weather and climate models. I am confident the agencies can reasonably deal with emerging decisions in these areas as they arise under the revised governance model.

8. **What are DOD's intentions with respect to the funding provided to them for NPOESS in fiscal year 2010?**

   Answer: DOD intends to leave the FY2010 funds that were appropriated for the NPOESS program in place. The full FY2010 funding for NPOESS program (50% of the contributions coming from each of NOAA and DOD) will largely still be going to those parts of the program for which they were originally designated – to continue ground system and instrument development for the NPP satellite as well as continue instrument development and algorithm development for subsequent Joint Polar Satellite System (JPSS) spacecraft that will fly in the afternoon orbit. It is important that those FY2010 funds remain in the program since the data are required by DoD and NOAA for their respective missions. Any reduction in those funds will almost certainly result in delays of the NPP satellite and a delay in the launch of JPSS-1, the follow-on afternoon satellite, thereby greatly increasing the risk of a gap in weather and storm forecasting capability of importance to both the civil and the defense community.

9. **What is OSTP doing to compel DOD to adopt a clear path forward?**

   Answer: OSTP is working with DOD to ensure a smooth transition. DOD officials have provided assurance to OSTP that the agency remains committed to a partnership with NOAA to preserve the Nation's weather and climate sensing capability. For the morning orbit, the current DOD plan for deploying DMSP satellites ensures continued weather observation capability. DOD will be working closely with the civil partners to ensure the relevant efforts continue productively and efficiently, and will ensure the requirements of the national weather and climate communities are taken into consideration in building the resultant program for the morning orbit. DOD leadership has indicated consistently to OSTP over the past several months strong commitment and support in FY2010 for ensuring minimal impacts of the restructure on the afternoon orbit capabilities.

10. **Why is there no fiscal year 2011 request for an operational scatterometer to replace Quickscat?**

   Answer: Although NOAA does not have a funding request for scatterometry data in FY2011, NOAA previously funded NASA's Jet Propulsion Laboratory to study possible satellite options to establish a sustained ocean surface vector wind (OSVW) observing system. The estimated costs of a satellite program were in the $1-$3 billion range. Given the costs, NOAA is exploring additional options, including partnerships, to meet OSVW requirements for both short- and long-term scenarios. Currently, NOAA has several ways to mitigate the loss of these space-based ocean surface vector winds data, such as using data from the Advanced Scatterometer (ASCAT) which flies onboard the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) satellites, called MetOp. NOAA is also seeking timely access to data from the Indian research satellite, Oceansat-2, which launched in September 2009 as a source of OSVW data, and from the Chinese who will launch a satellite with OSVW capability in the near future.

While the impact to tropical storm forecasting is limited, losing QuikSCAT data impacts wind and wave forecasts and warnings in the Open Ocean, as well as non-tropical storms in coastal areas, making those forecasts and warnings less accurate. Using other satellite and non-satellite tools, however, forecasters will continue to be able to track and provide warnings for ocean storms.

Climate observing systems and research including development of fine scale predictive models will be needed to support private and public investments in climate adaptation at the local, state and regional levels. This concern led to congressional direction to OSTP to deliver to us by April 1, a plan for achieving and sustaining global Earth observations. Requested and projected support for ground-based and space-based observations and the end-to-end supply chain of climate information and data products is evident in the budget proposed.

11. **Is this a result of the plan OSTP is developing, and how does this plan extend to agencies not in our subcommittee jurisdiction, such as the US Geological Service and the Department of Agriculture with its Ag Research Service and Ag Extension Agents?**

    Answer: OSTP has been actively engaged in interagency discussions on rebuilding a robust observations capability and ensuring an end-to-end supply chain of climate information and data products. The results of these discussions are evident in the 2011 Budget's substantial support for observations and climate information and data. This interagency coordination process includes all of the participating agencies in the US Global Research Program, including the U.S. Geological Survey and the US Department of Agriculture.

12. **What are the plans for a national climate service, and who will have the lead responsibility?**

    Answer: OSTP is working with agencies under the auspices of the National Science and Technology Council to articulate a national framework of leadership for climate services that addresses the nation's growing need for coordinated climate information and services to assist decision-making across public and private sectors. This effort will bring various agency initiatives together with an understanding of overall national needs and capabilities for delivering climate services. For example, NOAA has announced its intent to establish a NOAA Climate Service (www.climate.gov), which proposes to bring together under one line office several research, data, and coordination programs currently within the Office of Oceanic and Atmospheric Research; the National Weather Service; and the National Environmental Satellite, Data, and Information Service. In addition, DOI has announced Regional Climate Change Response Centers to synthesize and integrate climate change impact data and develop tools that the Department's managers and partners can use when managing the Department's land, water, fish and wildlife, and cultural heritage resources. These two initiatives propel the nation farther forward toward developing the tools necessary to help decisions under conditions of climate change. Just as the nation's climate research efforts require and benefit from interagency and academic partnerships, so too will the development and communication of climate information to users. No single agency is capable of providing all of the information and services needed to inform decision-making. OSTP's interagency effort will help clarify roles, responsibilities, and leadership of a national framework for climate services.

As I noted in my opening statement, this subcommittee has held two hearings on STEM education. From the testimony it is clear that the effectiveness of inquiry-based instruction in STEM education is needed at all levels, but implementation is woefully lacking.

13. What is the administration doing to correct this?

Answer: President Obama believes inquiry is fundamental to innovation. As he stated in his remarks launching the Educate to Innovate campaign in November, "Everyone in this room understands how important science and math can be. And it goes beyond the facts in a biology textbook or the questions on an algebra quiz. It's about the ability to understand our world: to harness and train that human capacity to solve problems and think critically, a set of skills that informs the decisions we make throughout our lives." It is also why the President highlighted "National Lab Day," a historic grassroots effort that connects thousands of science teachers with local resources and volunteers to do hands-on and inquiry-based learning, such as sampling local water or collecting energy efficiency data.

Furthermore, to bring inquiry-based instruction to scale, this Administration believes three levers are essential: (a) strong instructional materials that provide the tools and supports (e.g. lesson plans, lab equipment, assessments, tech) for teachers to allow for effective science instruction; (b) teachers with the support, knowledge and experience to implement these instructional materials in ways that make sense for their students, and (c) school and district leaders who can design and execute programs to provide the needed support at scale over time.

In both the priorities for federal investments, such as STEM-investments at the National Science Foundation, and with reauthorization of Elementary and Secondary Education Act, this Administration has focused on these three levers of impact.

14. Should use of inquiry-based science instruction be required of all institutions of higher education receiving federal research funding?

Answer: The Administration does not believe that an absolute requirement for inquiry-based instruction tied to federal research funding would be appropriate. However, the Administration is actively exploring opportunities to both highlight and take policy steps to incentivize the deployment and growth of programs that refashion entry level courses in science so that they are more inquiry-focused, as some leading institutions have done, and incentivize retention of first-year STEM students.

15. Witnesses stated that one obstacle to effective implementation of inquiry is that at the local level and in individual schools, decisions are generally made by education officials who lack understanding of STEM education; given that education at K-12 is primarily a state and local responsibility, what can the federal government do to stimulate support for inquiry-based STEM education at the grass roots level?

Answer: The President believes that federal leadership in education is important, but also that the scope and impact of federal efforts depend on strong partnership and collaboration with states and school districts. It's why Race to the Top competition gives a competitive priority to states that build comprehensive strategies for STEM education and build partnerships to achieve their plans. It is also why the President called on the 200,000 federal scientists and engineers to get involved in local and grassroots efforts, such as National Lab Day, to work alongside schools and teachers to improve STEM education.

In addition to investments under the Recovery Act, the President's FY11 Budget, and proposed reauthorization of the Elementary and Secondary Education Act, the Administration has focused on a few key levers of reform that are essential to effective STEM instruction: (1) improving teacher and principal effectiveness to ensure that every classroom has a great teacher, and every school has a great leader; (2) providing information to families to help them evaluate and improve their children's schools, and to educators to help them improve their students' learning; (3) implementing college- and career-ready standards and developing improved assessments aligned to those standards; and (4) improving student learning and achievement in America's lowest-performing schools by providing intensive support and effective interventions.

Witnesses indicated that the transfer of the math science partnerships program from NSF to the Department of Education was not resulting in effective STEM education reform. They also strongly advocated that responsibility for reform of STEM education, including whatever federal role there is in actual implementation of inquiry-based instruction, be vested in NSF as a science agency and not in the Department of Education.

16. **Do you agree with their statements – why or why not? And what would you recommend to the President?**

    Answer: We believe that a strong partnership between the Department of Education and the science agencies, especially the National Science Foundation, is essential. The Department of Education has substantial expertise in work with State education agencies and local school districts and this expertise has informed this Administration's strategy for overall education reform. Concurrently, the National Science Foundation has deep relationships with the scientific community that has made it a leader in developing cutting-edge materials and strategies in STEM education. We believe strong collaboration is therefore necessary and is occurring under this Administration.

17. **If this responsibility were assigned to NSF, what would be the benefits and your concerns?**

    Answer: We believe that a strong partnership between the Department of Education and the National Science Foundation is the best option to meet the goals of the math science partnerships program.

The Administration has embraced the Advanced Technology Education program and has sustained last year's increase with a request for $64 million. This program engages community colleges in meeting workforce needs for technically trained individuals.

18. **Given the President's statements regarding the need to achieve universal education above the high school level and the large proportion of college students being educated by community colleges, what should be done to strengthen STEM education generally at community colleges?**

    Answer: In an increasingly competitive world economy, America's economic strength depends upon the education and skills of its workers. In the coming years, jobs requiring at least an associate degree are projected to grow twice as fast as those requiring no college experience. To meet this demand, President Obama has set two national goals: by 2020, America will once again have the highest proportion of college graduates in the world, and community colleges will produce an additional 5 million graduates.

As the largest part of the nation's higher education system, community colleges enroll more than 6 million students and are growing rapidly. Community colleges are building the workforce of tomorrow as well as retraining the workforce of today. Today, 59% of new nurses and almost half of all teachers, including STEM teachers, start or receive part of their education at these same institutions. And schools across the country are poised to respond to the changing economy to help train workers for clean energy and other high-demand fields.

Last July, President Obama proposed the American Graduation Initiative to invest and reform community colleges in order to help American workers get the skills and credentials they need to succeed. The recently passed Health Care and Education Reconciliation Act includes $2 billion over four years – one of the largest federal investments ever – for community colleges. These resources will help transform community colleges for today's economy. With these resources, community colleges across the country will be able to develop partnerships with businesses to design training that is relevant to local labor markets, work with other institutions to expand course offerings and promote transfer of credit, improve adult education, expand the provision of comprehensive, personalized support services to help students plan their careers, stay in school, and graduate, and, create open online course materials that can help students learn more, and learn better, in less time.

Ensuring that businesses in STEM fields participate in the partnerships and building the capacity of community colleges to provide STEM support will help support a greater number of students accessing STEM instruction and entering STEM fields. Online learning initiatives will also be a place to strengthen the delivery of STEM instruction. Apart from higher education, the Administration's recently released Blueprint for the reauthorization of the Elementary and Secondary Education Act (ESEA) will ensure that K-12 programs are preparing our students to be college and career ready, so we can reduce the remedial education burden that is often placed on community colleges. This will free community colleges to do what they do best; provide affordable accessible STEM workforce training, and prepare students for transfer into other degree programs.

19. **What role should community colleges be playing in the reform of STEM education and the broad inclusion of inquiry therein?**

Answer: Community colleges have an important role to play. They offer a direct connection between the needs of the workforce and the preparation of the students. Community colleges provide an opportunity for businesses to identify what is needed from STEM education to ensure more students enter STEM fields prepared to succeed. Community colleges also provide an opportunity to work with non-traditional students and diverse students which is an opportunity to develop models for inquiry for all people which can be shared with other institutions.

The US Program in human spaceflight has reached a crossroads, and the President is proposing a shift in emphasis to development of new technologies to enable human exploration beyond the International Space Station while extending use of Station from 2015 to at least 2020.

20. **This significant change to the program of record, including cancellation of the Constellation program, requires congressional action; when will the administration send a legislative proposal or budget amendment to Congress, and what form will proposed legislation take?**

    Answer: This issue is still under review and discussion within the Administration, thus we do not yet have a definitive response on the timing or form of such a proposal. Nonetheless we intend to work closely with the Congress in implementing the President's new plan for NASA and will provide further information on next steps as soon as we are in a position to do so.

21. **Doesn't this represent an abandonment of US leadership in human spaceflight established by the six successful Apollo moon landings 40 years ago?**

    Answer: No, rather this signifies the beginning of a new era in space involving new approaches and technologies. The President's budget will extend American leadership in space exploration by increasing our technological capabilities, reducing costs, and creating new mission possibilities and opportunities as we move forward into the 21st century. This will enable the United States to pursue exploration in a fundamentally different way from today's norms, while also providing opportunities for genuine cooperation with other nations.

    At the highest level, the Administration, including myself and my staff, as well as NASA senior leadership, closely reviewed the Augustine Committee report, and came to the same conclusion as the Committee: The Constellation program was on an unsustainable trajectory. The Administration determined that, given the current budget environment, Constellation's funding needs would have required terminating support of the International Space Station (ISS) in 2016 and ESMD would not have had sufficient resources to significantly advance the state of the art in the technology areas that would be needed to enable lowering the cost of heavy-lift access to space, and developing closed-loop life support; advanced propulsion technology; and radiation protection and other technologies on a faster schedule. The President determined that what was truly needed for beyond-LEO exploration was game-changing technologies; making the fundamental investments that will provide the foundation for the next half-century of American leadership in space exploration. At the same time, under the new plan, NASA would ensure continuous American presence in space on the ISS throughout this entire decade, re-establish a robust and competitive American launch industry, start a major heavy lift technology program years earlier, and build a technological foundation for sustainable beyond-LEO exploration of our moon, near-Earth asteroids, Lagrange points, and ultimately Mars.

The President's FY 2011 budget request outlines an innovative course for human space exploration, but does not change our goal – extending human presence throughout our solar system. NASA's exploration efforts will focus not just on our Moon, but also on near-Earth asteroids, Lagrange points, and ultimately Mars. While we cannot provide a date certain for the first human visit, with Mars as a key long-term destination we can identify missing capabilities needed for such a mission and use this to help define many of the goals for our emerging technology development. The research and technology investments included in this budget describe the many near-term steps NASA will be taking to create the new knowledge and capabilities required for humans to venture beyond low-Earth orbit (LEO) to stay.

For example, the technologies necessary to withstand the harsh radiation on the way to Mars don't yet exist. Neither do: rocket engines that can take us further and faster more affordably; the on-orbit refueling capabilities that would greatly facilitate a Mars sample return mission; automated and autonomous rendezvous and docking systems; and closed-loop life support systems necessary to allow astronauts to eat and breath on long journeys.

In addition, our new approach includes a steady stream of precursor robotic exploration missions to scout locations and demonstrate technologies to increase the safety and capability of future human missions while also providing scientific dividends. We are going to touch the surface of solar system destinations such as the Moon, near-Earth objects, and Mars with ever more frequency and sophistication, with robots leading the way for later human explorers.

Combining an aggressive test and demonstration program for new enabling technologies with new scouting missions offers our Nation a better, far more sustainable strategy for space exploration – one that takes a step-by-step approach toward our long-range objectives and ambitions while providing near term benefits and achievements.

22. Through on-orbit assembly of the Space Station and servicing of the Hubble Space Telescope, astronauts have demonstrated their value in construction in the challenging space environment; how will continued use of the Station take advantage of this capability?

Answer: The International Space Station will be home to new research projects in fundamental biology and physical sciences. In addition, it will be the ultimate space-based research and technology test-bed, as NASA's new flagship technology demonstration projects and foundational research and development efforts will rely heavily on the International Space Station as a unique platform to support this work. For example, NASA will implement and manage a broad test program of next-generation technologies in multiple flight demonstrations over the next decade, in areas like in-orbit propellant storage and transfer, automated and autonomous rendezvous and docking, lightweight inflatable modules for exploration, and advanced closed-loop life support and tele-robotic operations. These activities can all take advantage of the expertise learned to date on the International Space Station and Hubble servicing missions.

23. What are the explicit and implicit assumptions behind reliance on commercial provision of human transportation to and from low Earth orbit?

Answer: Several factors played a role in the Administration's decision to pursue commercial crew services for transporting astronauts to and from Low Earth Orbit. For example, the Augustine Committee found that commercial crew "creates the possibility of lower operating costs for the system and potentially accelerates the availability of U.S. access to low-Earth orbit by about a year, to 2016." Given that the Augustine Committee found that the Ares I would not be available until 2017 at the earliest, the commercial crew approach thus provides an opportunity to acquire an American capability to transport astronauts to the International Space Station sooner.

In addition, NASA has already pioneered a new approach in its handling of commercial cargo services, and the commercial crew program will benefit from this experience. More specifically, NASA has worked with commercial companies to help them develop new capabilities for delivering cargo to the Space Station and has let contracts that pay the commercial companies for actually delivering. Just like NASA has established specific criteria for ensuring that commercial services that supply cargo transportation to (and dock with) the Space Station don't put Space Station crew members at risk, NASA will similarly establish standards and an oversight process for ensuring that commercial crew transportation vehicles are safe. Further, over the next several years, it is anticipated that there will collectively be over fifty flights to low-Earth orbit by many of the launch vehicles that could provide the basis for a commercial crew capability – providing significant opportunities to demonstrate reliability and refine operational concepts.

America's aerospace industry has always built the nation's crew launch vehicles. Nearly fifty years ago, American industry human-rated an existing launch vehicle and successfully created the Gemini system, which safely flew 10 crewed missions within five years of its initiation. America has long relied on the ingenuity and entrepreneurial spirit of its commercial entities to drive innovation, and space should ultimately be no different. We also still depend upon commercial suppliers to launch most of NASA's satellites, as well as our Nation's weather satellites and the valuable national security satellites that are critical to our war-fighting ability and our nation's defense. As such, leveraging commercial or private sector goods and services is not new territory for NASA, including in the crew transportation arena. But this new way of procuring crew transportation services holds the promise of enabling significantly reduced costs in the future, while incentivizing competition and innovation in the development of these capabilities.

Another key factor is that the opportunity to compete for crew transportation services to the International Space Station is open to the broad aerospace industry – new or emerging companies, and traditional aerospace companies (including any company that had been part of the Constellation program). Any company can, if it chooses, compete with others as part of the new commercial crew transportation services program.

Finally, with respect to the safety of a commercial crew transportation system, the Augustine Committee ultimately determined that safety did not appear to be a pivotal differentiating factor among the various launch options included in its final report. Specifically, the Committee wrote that NASA planned Ares I vehicle used a *"high-reliability rocket and a crew capsule with a launch-escape system. But other combinations of high-reliability rockets and capsules with escape systems could also provide that safety. The Committee was unconvinced that enough is known about any of the potential high-reliability launcher-plus-capsule systems to distinguish their levels of safety in a meaningful way."*

The US federal science and technology enterprise includes a wide variety of institutions and funding mechanisms ranging from competitively selected grants to universities to cooperative institutes and centers funded for 5 to 10 years to FFRDCs such as the DOE national labs and user facilities to research centers such as NIH and NASA where the staff are primarily government employees.

24. Do the costs of R&D vary significantly across this mix, and should there be changes in the mix in the interest of improving R&D value per dollar?

Answer: We do not have reliable data on the costs of performing R&D based on type of performer, for several reasons. One is that it is difficult to compare units of R&D across performers: university researchers typically produce research papers through grants, Federal researchers may produce research results or products directly relevant to their agency colleagues in carrying out agency missions, and national laboratory researchers may work in large teams on multi-disciplinary projects with numerous types of outputs such as patents or prototypes. A second reason is that Federal agencies do not select performers primarily on cost considerations; instead, performers are selected based on their suitability for and expertise in performing a particular kind of research or development project of relevance to that agency's mission. And a third reason is that direct Federal support of R&D is just one element of the costs of doing R&D, making a calculation of R&D value per dollar complex; in universities, for example, direct Federal support of R&D captures only part of the cost of performing research; recoverable and unrecoverable indirect costs, state and local government support, and separate Federal support for graduate education are also costs of performing R&D. Similarly, Federal laboratories perform research with a mix of project-based funds, general operating support, and external funds.

Each year, the National Science Board compiles an extensive digest of key science and engineering indicators.

25. Based on these indicators and your own observations, what is the state of the American science and technology enterprise including research, development, education, and infrastructure?

Answer: The latest edition of *Science and Engineering Indicators* and my own observations suggest that the state of U.S. science and engineering is strong, but that U.S. dominance of world science and engineering has eroded significantly, primarily because of rapidly increasing capabilities among East Asian nations, particularly China. We remain the world leader in most aspects of the science and technology enterprise, including R&D funding, patents, research papers, top-notch science and engineering graduates, world-leading scientific institutions, and the state of research infrastructure. But our lead is shrinking, partially because of the emergence of strong capabilities in developing nations and partially because of a relaxation in U.S. efforts. We can do better. America still can, and indeed must, be an innovation machine through strong leadership in science and technology. Clearly, however, technological and economic superiority is not our birthright. It is something that in the past we have earned—earned as a result of smart investments in fundamental science and targeted investments in the next big things—and it is something we must get serious about earning again, so we can continue to lead the world in the next round of modernization and creativity.

That is why the President has set the bold but achievable goal of investing 3% of GDP in research and development—to beat, for the first time, the level of R&D investment at the height of space race. Investing in innovation is not a luxury today—it is a necessity.

And that is why the 2011 Budget sustains the President's commitment to research and development funding, innovation, STEM education. With these investments, we can continue to support the workforce of today as well as the entrepreneurs and industries of tomorrow, to keep the pipeline of American productivity fully pressurized and provide the jobs, the security, and the position of global leadership that previous generations worked so hard to attain.

26. How does the US compare with other countries and regions?

Answer: By many measures, the United States retains a dominant position in science and technology. The United States, for example, is still #1 in R&D expenditures with a third of the world total, exceeding the combined expenditures of the 27 European Union nations. The United States continues to be the top producer of published science and engineering articles. The United States has the highest share of value-added in high-technology manufacturing with 30 percent of the global total. But other nations, especially nations in East Asia, are expanding dramatically their capabilities in science and technology. Between 1996 and 2007, for example, the average annual growth of R&D expenditures in the United States was a robust 5 percent. But China's average annual growth of R&D expenditures exceeded 20 percent. Therefore, the U.S. share of world R&D expenditures has declined; the same trends are apparent in other indicators such as patents, articles, and science and engineering workforce. (Data are from *Science and Engineering Indicators 2010.*)

27. How has the recession affected private sector R&D?

Answer: Data on the impact of the recession on private sector R&D investments are still incomplete. The impacts of the recession on companies' R&D plans in 2009 are still being tabulated by the Census Bureau and the National Science Foundation. The latest preliminary NSF data we have on industry R&D for 2008 show that industry invested $268 billion in R&D that year, up 8.5 percent compared to 2007 despite the impacts of the recession in the latter half of the year. There are abundant anecdotes of companies scaling back their R&D investments in response to economic conditions last year, but there are also encouraging signs that U.S. companies plan to increase their R&D investments in 2010. The Battelle 2010 Global R&D Funding Forecast, for example, expects U.S. industry R&D spending to resume growth in 2010 after a drop in 2009.

28. What changes and challenges do you predict for US science and technology in the coming years, and what do you recommend this committee do to further strengthen US R&D?

Answer: The challenges for U.S. science and technology are articulated in the OMB-OSTP memo on Science and Technology Priorities for the FY 2011 Budget and the Administration's Strategy for American Innovation.

As for the Committee's role, at a difficult time in the nation's history, the President's 2011 Budget proposes to invest in science, technology, and innovation today to meet the challenges of tomorrow, building on the Administration's collaborations with this Committee over the past year on the Recovery Act, 2009 appropriations, and 2010 appropriations. The continued support of this Committee for the important R&D investments under its jurisdiction is essential to our combined efforts to further strengthen the US R&D enterprise of tomorrow.

Ranking Member Frank R. Wolf
Questions for the Record

Space Exploration

1. **What are the mission goals of the new program, and on what timetable will they be achieved?**

   Answer: The over-arching goal of the President's budget is to expand American leadership in space exploration by increasing our technological capabilities, reducing costs, and creating new mission possibilities and opportunities as we move forward into the 21st century. This will enable the United States to pursue exploration in a fundamentally different way from previous expectations.

   There also is an important strategic shift underpinning the President's new strategy for U.S. human exploration activities. For too long our nation has selected arbitrary space exploration destinations and time lines that have led to fundamentally challenged or unachievable programs. The Augustine Committee found that the U.S. human spaceflight program was on an unsustainable trajectory and that NASA was pursuing goals that did not match allocated resources. That approach has been harmful to U.S. space exploration capabilities and goals, while also pulling vital resources from other NASA mission areas. Space exploration is too important in terms of innovation, inspiration, and national leadership to continue down this non-productive and ineffective path. Therefore, we must strive to ensure that our Nation's human spaceflight program is real, can produce tangible benefits, is flexible, and can be achieved. We believe that a sea-change in how we think about space exploration programs is necessary if we want to escape the prior mold and put the nation on a trajectory that will help us achieve our aspirations in space.

   The President's FY 2011 budget request outlines an innovative course for human space exploration, but does not change our goal – extending human presence throughout our solar system. NASA's exploration efforts will focus not just on our Moon, but also on near-Earth asteroids, Lagrange points, and ultimately Mars. As the President explained in his April 15 speech at the Kennedy Space Center, these exploration missions will begin early next decade with a set of crewed flights to test and prove the systems required for exploration beyond low Earth orbit (LEO). By 2025 we expect new spacecraft designed for long journeys to be ready for the first-ever human missions beyond the Moon into deep space, beginning with a mission to an asteroid for the first time in history. And by the mid-2030's, we believe we will be in a position to send humans on an orbital Mars mission and return them safely to Earth, with a landing on Mars to follow. With these missions and time lines as reference points, we can identify the missing capabilities needed for such efforts and use this information to help define many of the goals for our emerging technology development activities. The research and technology investments included in this budget support the many near-term steps NASA will be taking to create the new knowledge and capabilities required for humans to venture beyond LEO to stay.

With such objectives in mind, the President has made a decision to place us on a course of prudent investments in advanced technology, with the resulting pace of development helping to inform decisions about which deep-space destinations will be pursued when. Some of the key investments and activities in the new strategy that will help achieve this goal are summarized below.

The International Space Station and Crew Transportation to LEO

The first element of the new approach for NASA is to work with our international partners to extend the life (and make better use) of the International Space Station (ISS), while also partnering with the aerospace industry in a new way to provide crew transportation services to this orbiting research outpost. In the previous Administration, NASA had made no commitments to supporting ISS beyond 2015 and assumed that funds for the ISS would be redirected towards the Constellation program. Prior NASA Administrator Michael Griffin often said it was a "glaring omission" to treat the Space Station in this way, and that continuing the ISS should be "non-negotiable." Nonetheless, that administration saw funding the ISS after 2015 as being in conflict with the Constellation program and formulated its exploration plans and budgets on the assumption that the Space Station would not be funded. By contrast, the Augustine Committee found that the return on investment of ISS to both the United States and its international partners would be significantly enhanced by an extension of the planned lifetime of the ISS, likely to beyond 2020. President Obama similarly has recognized the value of the ISS to our space program, and to our relationship with our international partners. As such, he is committing to continue the operations of the ISS, likely to 2020 or beyond, as the Augustine Committee recommended.

In terms of supporting mission goals, the ISS will be home to new research projects in fundamental biology and physical sciences. In addition, it will be the ultimate space-based technology test-bed, as NASA's new flagship technology demonstration projects and foundational research and development efforts will rely heavily on the International Space Station as a unique platform to support this work.

Commercial crew transportation capabilities are also an important part of the new strategy. The Augustine Committee found that utilizing commercial crew transportation services for launching astronauts to LEO "creates the possibility of lower operating costs for the system and potentially accelerates the availability of U.S. access to low-Earth orbit by about a year, to 2016." Given that the Augustine Committee found that the Ares I would not be available until 2017 at the earliest, this provides an opportunity to get an American capability to transport astronauts to the ISS sooner.

NASA has already pioneered a new approach in its handling of commercial cargo services. Specifically, NASA has worked with commercial companies to help them develop new capabilities for delivering cargo to the Space Station and has let contracts that pay the commercial companies for actually delivering. Just like NASA has established specific criteria for ensuring that commercial services that supply cargo transportation to (and dock with) the Space Station do not put Space Station crew members at risk, NASA will similarly establish standards and an oversight process for ensuring that commercial crew transportation vehicles are safe for NASA astronauts. Further, current manifests for NASA and the Department of Defense indicate that over the next several years there will collectively be on the order of fifty flights to low-Earth orbit by many of the launch vehicles that could provide commercial crew transportation – providing significant opportunities to demonstrate reliability and refine operational concepts.

We already rely on commercial suppliers to launch most of NASA's satellites, as well as our Nation's weather satellites, and the valuable defense satellites that are now critical to our war-fighting ability and our nation's defense.

The United States has fallen behind in commercially competitive launch services, but a new generation of American entrepreneurs is leading new efforts in this domain and has the potential to help our private sector play a transformative role. A greatly strengthened U.S. commercial space industry, undertaking astronaut transportation to the International Space Station, would bring needed competition and help catalyze the development of other new businesses capitalizing on affordable human access to space. The United States can and should lead these new industries.

American aerospace firms have always ultimately been the organizations that have built the nation's crew launch vehicles. Nearly fifty years ago, American industry human-rated an existing launch vehicle and successfully created the Gemini system, which safely flew 10 crewed missions within five years of its initiation. America has long relied on the ingenuity and entrepreneurial spirit of its commercial entities to drive innovation, and space should ultimately be no different.

Exploration Beyond Earth's Orbit

The Augustine Committee found that a landing on the Moon would not have been possible until "at least the 2030's, if ever," given the costs of the Constellation Program and previous budgetary projections. Even if the Space Station was abandoned early to save money and $45 billion more funding was added to NASA's budget over the next decade, a landing on the Moon would not have been possible until the mid-to-late 2020's. And if the International Space Station was not abandoned, NASA would need almost $60 billion more through 2020 in order to return U.S. astronauts to the surface of the Moon by 2025 or so. The Committee went on to conclude that a root cause of this troubled state was a decades-long, systemic under-investment in new technology and innovation. Thus we must first revitalize NASA's technology development activities so that we can pursue such exploration in a fundamentally different and more effective way going forward.

The President has laid out an ambitious new exploration program specifically tailored to address these needs. This is a program of actively testing and demonstrating new technologies while investigating potential destinations for human spaceflight, while also matching goals and timetables to the pace of technological advance and growing knowledge. It is a program aimed at creating the needed transformational technologies without forcing on the taxpayer the burden of paying to try to stretch old technologies beyond their capabilities.

The opportunities for such technology development activities are numerous. For example, we do not yet have the technologies necessary to withstand the harsh radiation on the way to Mars; rocket engines that can take us further and faster more affordably; the on-orbit refueling capabilities that would greatly facilitate a Mars sample return mission; automated and autonomous rendezvous and docking systems; or closed-loop life support systems necessary to allow astronauts to eat and breath on long journeys. The President's FY 2011 budget provides the necessary funds to initiate substantive research to develop these technologies – research and development that will need to continue for several years in order to tackle many of the most difficult challenges. In parallel, under the President's new plan, NASA will actively investigate a range of potential destinations for human spaceflight, sending robotic precursor missions to find the best sites for human exploration and clarify the requirements for humans' reaching them and operating there, better informing choices about where to go and when.

This is a highly proactive approach – one that will develop, test, and demonstrate new technologies and will use the International Space Station as a true laboratory complex to facilitate more advanced development of capabilities. This work will be critical to supporting an informed decision about future heavy lift launch vehicle needs, as described below in answer to Question 3. Through such activities, the workforce that supports human space flight development efforts will have the opportunity to be engaged and active in demanding and worthwhile pursuits.

2. The Augustine report outlined five options. "Option 2" was extend ISS to 2020; make investments in technology development and commercial transport to low-earth orbit; provide funds for enhanced usage of the ISS; all under current budget constraints. Augustine said that this option would not deliver heavy-lift capability until the late 2020's and does not have funds to develop the systems needed to land on or explore the Moon in the next two decades. Does that timetable description also apply to the President's proposed program?

Answer: The Augustine Committee's "Option 2" assumed that certain key and expensive elements of the Constellation Program would continue (*e.g.*, a full-fledged Orion crew capsule and a variant of the Ares V heavy lift vehicle). As envisioned by the Committee, this option was based on the FY2010 budget profile and would have been subject to the long program schedules as described in this Question and in the answer to Question 1.

In contrast, the President's new plan adds $6 billion in funds to NASA's top-line budget over five years relative to the FY2010 profile and ends the Constellation Program in favor of an alternative approach to human spaceflight that the President articulated in his April 15 speech at the Kennedy Space Center. This approach is intended to lead to more cost-effective and flexible transportation architectures (including a suitable heavy lift system), attainable on a faster timetable than that projected for Option 2 in the Augustine Committee's assessment.

More specifically, in his speech on April 15, the President laid out the goals and strategies related to the FY 2011 budget request for human exploration of our solar system, including a sequence of deep-space destinations matched to growing capabilities which progress step-by-step into space. In doing so, he announced that his Administration will make a specific decision in 2015 on the design of a new heavy-lift vehicle. A decision in 2015 means that major work on building a new heavy-lift rocket will likely begin two years earlier than under the Constellation Program.

The FY 2011 budget request introduces a new Heavy-Lift Research and Development (R&D) Program that will focus on developing technologies to help reduce cost and enhance operability by improving our space launch propulsion technologies. This effort will include development of a U.S. first-stage hydrocarbon engine for potential use in future heavy lift (and other) launch systems, as well as basic research in areas such as new propellants, advanced propulsion materials manufacturing techniques, combustion processes, and engine health monitoring. Additionally, NASA will initiate development and in-space testing of in-space engines. Areas of focus could include a liquid oxygen/methane engine and also low-cost liquid oxygen/liquid hydrogen engines. This work will build from NASA's recent R&D experience in this area, can increase our heavy-lift and other space propulsion capabilities, and significantly lower operations costs – with the specific goal of taking us farther and faster into space. In support of this initiative, NASA will explore cooperative efforts with the Department of Defense. NASA will also develop a competitive process for allocating a small portion of these funds to universities and other non-governmental organizations. This research effort along with many of our new technology initiatives will be coordinated with the broader Agency technology initiative led by NASA's new Chief Technologist.

Additionally, the President outlined how he wants NASA to restructure the Orion Crew Exploration Vehicle project and thereby develop a simpler and more efficient capsule that will be focused on crew emergency escape from the International Space Station. Therefore, as part of the President's new plan for NASA, the development work already performed on this capability will be re-oriented to meet the important safety requirement of providing stand-by emergency escape capabilities for astronauts on the Space Station. This effort also will help establish a technological foundation for future exploration spacecraft needed for human missions beyond low Earth orbit.

3. **The Shuttle program is being closed down at the end of this year. NASA was already faced with the difficult task of transitioning the Shuttle workforce into the Constellation programs. Now you are proposing to terminate the Constellation program at the same time. What do you anticipate as the impacts of this decision on the workforce, both civil service and contractors? How many jobs do you estimate will be lost, and when? And what measures do you plan to take to minimize the impact of job losses, and the negative impact on the Nation's space industrial base?**

Answer: Since the previous Administration's announcement in 2004 of the termination of the Shuttle program, we have known that as many as 8,000-12,000 jobs will be affected by the retirement of the Shuttle. The President is committed to flying out the remaining 3 shuttle flights in a safe and prudent way, providing an additional $600 million in funding for the Shuttle to fly out the manifest even if the schedule for completion slips and extends into Fiscal Year 2011. This is a significant policy change relative to the course chosen by the previous administration, which had imposed a hard deadline of September 30, 2010, whether or not the Shuttle's principal job of completing and supplying the International Space Station (ISS) had been finished. NASA's Aerospace Safety Advisory Panel has recommended conclusively against extending the Space Shuttle beyond its current manifest, and the budget is consistent with that recommendation.

The President's new plan for NASA will result in an increase in the total number of rocket launches from Kennedy Space Center in Florida compared to the old plan, as NASA tests new technologies in space; launches robotic precursor missions to the Moon, asteroids, and other destinations; and resupplies and enhances the capability of the ISS. In support of this more demanding launch schedule, and in recognition of Kennedy Space Center's role in future exploration activities, the new plan proposes strategic new investments of $1.9 billion at KSC that will lead to hundreds of new jobs, upgrade facilities for the 21st century, and help ensure that KSC will remain a world-class launch port for decades to come, attracting new commercial business in addition to reliably and efficiently supporting government flights. This long-overdue modernization of KSC's facilities -- many of which date to the 1960s -- in concert with ongoing modernization of the Florida launch range, will allow KSC to continue its critical role in future commercial and governmental activities and help Florida better weather the transition after the shuttle's retirement.

The investments in NASA, and the corresponding reorientation of the human space flight program, that are supported by the President's new plan will create thousands of jobs nationwide, helping to offset job losses associated with the end of the Shuttle program and the termination of Constellation. For example, the President's commitment to energize a new commercial spaceflight industry – investing $6 billion over the next five years -- could lead to as many as 10,000 new jobs alone nationwide based on non-government estimates. Also, the President's new plan for NASA will create 2,500 more jobs in Florida over the next five years as compared to NASA's old plan. The budget also makes major investments in the next five years for the development, testing, and manufacture of new technologies – like $4 billion over five years for a new program in cross-cutting space technology research to be managed by NASA's new Chief Technologist to benefit NASA, the commercial space industry, and users on Earth. These investments will not only help support and create new jobs today, but could help lead to the new industries and jobs of the future.

A renewed focus on technology development will have several benefits for the U.S. industrial base and our expertise in this arena. Engineers will have greater opportunities to work on more projects from end-to-end, gaining invaluable experience and creating opportunities to learn. Technology will be able to evolve at a much more rapid pace, as new techniques can be tested on successive demonstrations. Multiple demonstration projects launching to space (starting before 2015) will keep the operational launch workforce in Florida more engaged and productive than the Constellation alternative, which would not have had any work for those critical people until at least 2017 as found by the Augustine Committee.

As explained in the response to Question 2 above, NASA will be working on useful new rocket-propulsion capabilities as well. For example, the new program funds development of a new large hydrocarbon rocket engine. In addition to its utility for future heavy-lift launch vehicles for exploration, a rocket engine in this class would be well-suited to replacing the Russian rocket engine that powers one of the two commercial rockets that lift national security payloads to orbit (as well as potentially other U.S. vehicles). These efforts also will help retain and even expand the capabilities and expertise residing in a key sector of our space industrial base.

Climate Change

4. Leaked emails about suppressing data and dissent, and now several errors found in the UN's IPCC report make clear the need to restore integrity to climate science. What role does OSTP play in validating the data and conclusions contained in IPCC reports, and what do you plan to do to improve the quality and integrity of the science that will inform our climate policies?

Answer: The Obama Administration is committed to upholding the principles of scientific integrity, including raising the level of transparency and openness in the conduct and use of science in general, and climate science in particular. OSTP participates in many ways in the efforts leading up to IPCC reports, from working with U.S. federal agencies to help set priorities for research whose findings become part of IPCC assessments, to reviewing nominations of IPCC authors and reviewers from the United States, to leading US delegations to the IPCC plenaries. OSTP's multifaceted forms of engagement with IPCC processes provide ample opportunity for OSTP interventions to monitor and strengthen those processes, and we are doing so continually. As regards validation of data and conclusions, however, OSTP does not have the resources to add yet another layer of detailed and comprehensive review of the vast body of data and findings compiled and summarized by the IPCC, on top of the layers of review which begin with the peer reviewers for the scientific journals in climate-related fields (whose articles are the principal raw material for the IPCC's efforts) and which continue with the critical scrutiny of the hundreds of distinguished authors of the various chapters in the IPCC's reports and the thousands of distinguished reviewers that the IPCC engages to check this material. What OSTP does do is track discussions arising in the scientific community around issues being addressed by the IPCC and dig deeper, through our own review of specific key points and through consultation with experts, where this seems warranted.

The conclusion I have reached from my own close tracking of the performance of the IPCC, both before and after joining the Obama administration, is that mistakes and misjudgments in the IPCC assessments have been remarkably few in number and modest in importance given the wide scope and enormous volume of material reviewed – and the thousands of pages written by IPPC authors – in this effort. (This conclusion is shared by the other subject experts in OSTP, including those who stayed on from the previous Administration's team, and by the vast majority of subject experts around the world.) The procedures of review and re-review through which the IPCC has achieved this performance are exceptionally rigorous – much more so than those of even the most reputable scientific journals. When lapses do occur, it is in the nature of the continuing scrutiny that such findings receive that the lapses tend to be uncovered over time

– as they were in the cases of the erroneous projected date of disappearance of Himalayan glaciers and the erroneous figure for the fraction of the land area of the Netherlands that lies below sea level. Discovery of such mistakes tends to lead not only to their correction going forward but also to examination and remedy of the lapses in the review process that led to them; this, too, is happening in the instances mentioned, and OSTP is consulting with IPCC leadership in that effort. The e-mail exchanges among a number of climate scientists that came to light last year show that climate scientists are human, too, and that increased efforts to ensure openness and transparency in the conduct of climate science are warranted (consistent with the scientific-integrity principles that President Obama enunciated a year ago); OSTP is working toward that end. But nothing that has come to light in those e-mails or in the isolated missteps of the IPCC provides reason for doubting the core findings about climate change that have emerged from the work of thousands of scientists over decades, published in tens of thousands of peer-reviewed articles, and certified in dozens of major reviews by authoritative bodies besides the IPCC.

5. **NOAA has announced its intent to create a NOAA Climate Service. There is no corresponding proposal in the FY11 budget, and no required notifications have been submitted to the Committee. It appears that NOAA may intend to establish a Climate Service primarily by breaking off pieces of the Office of Oceanic and Atmospheric Research (OAR). The current OAR structure was established in 2005 to specifically to unify and strengthen the role of science in NOAA programs. Have you reviewed and approved a reorganization plan from NOAA?**

   Answer: I have neither formally reviewed nor approved a final reorganization plan. NOAA briefed OSTP on the outlines of its draft plan to stand up a NOAA Climate Service. Over the coming months, NOAA and the Department of Commerce will develop and submit a reprogramming package to the White House Office of Management and Budget and Congress for approval. NOAA's proposal draws heavily on existing OAR capacity, and does so naturally since OAR's Climate Program Office (CPO), Geophysical Fluid Dynamics Laboratory, and Earth System Research Laboratory have long been viewed as core capabilities required for climate science and services. NOAA's draft plan also calls for elements of OAR beyond the CPO to be transferred to the proposed NOAA Climate Service. I understand that details of how these elements will evolve are still under discussion within NOAA.

6. **The current OAR structure was based upon the recommendations of eminent scientists and was endorsed by NOAA's Science Advisory Board. Does NOAA's plan propose substantial changes to that structure?**

   Answer: The details of the reorganization are still under discussion within NOAA. I understand that as NOAA is working on its plans for a NOAA Climate Service, the agency is simultaneously undertaking an effort to strengthen science. They are actively involving its scientists and science leaders from across the agency in the development of a research strategy to ensure a strong and vibrant NOAA-wide science enterprise for the future.

7. **As the President's Science Advisor, are you concerned about the science function at NOAA being impacted by a NOAA reorganization plan that undoes the current OAR line office structure?**

   Answer: I am confident that NOAA, under the leadership of Dr. Jane Lubchenco, a highly respected marine biologist who is viewed as a champion for science within NOAA, is giving due consideration to its science enterprise as it works on a reorganization plan. In fact, Dr. Lubchenco has made strengthening science across the agency a top priority for NOAA, which is critical evolving and/or enhancing all NOAA services. NOAA depends on the new capabilities emerging from its research and development investments to provide enabling tools and technologies required for executing its entire mission. It is my understanding that NOAA is considering the various strengths of different options for reorganizing its climate programs, and involving its scientists and science leaders from across the agency in the development of a research strategy to ensure a strong and vibrant NOAA-wide science enterprise for the future.

8. **NOAA is not the only agency of the Federal government involved in climate issues. Does the Administration plan to submit a proposal to establish a Climate Service that includes programs and activities outside NOAA?**

   Answer: OSTP is working with agencies under the auspices of the National Science and Technology Council to articulate a national framework for a climate service enterprise that addresses the nation's growing need for coordinated climate information and services to assist decision-making across public and private sectors. This effort will bring various agency initiatives (e.g., NOAA's proposed Climate Service (www.climate.gov) and DOI's Regional Climate Change Response Centers) together with an understanding of overall national needs and capabilities for delivering climate services. Just as the nation's climate research efforts require and benefit from interagency and academic partnerships, so too will the development and communication of climate change information to users. No single agency is capable of providing all of the information and services needed to inform decision-making. OSTP's interagency effort will help clarify roles, responsibilities, and leadership of the agencies in a national framework for climate services.

NPOESS

9. The FY11 budget proposes a split in the NPOESS program, and funds new separate programs in NOAA and DOD. The NOAA program costs over $1 billion in FY11. What will be the estimated life-cycle costs of the new programs in comparison to the costs of NPOESS? And describe the changes in what will be delivered to NOAA, and the changes in capabilities of the final products?

Answer: The joint Department of Defense-NOAA NPOESS Program of record was estimated to have a life-cycle cost of $13.9 billion; however, the Integrated Program Office indicated that those costs would increase by $1-2 billion. With respect to the cost of the restructured program, I am unable to provide a new total since DoD has not yet completed its assessment of the cost of implementing its responsibility to continue observations in the early morning orbit. For the afternoon orbit, it will cost $11.9 billion (which includes the $2.9 billion invested through FY2010) for NOAA, with NASA as its acquisition agent, to implement JPSS.

The projected costs for NOAA are larger than their previously planned 50% contribution to the NPOESS program for two reasons. First, NOAA's JPSS is assuming total control of the acquisition of the instruments and development of the ground system that were in the former NPOESS program that will fly in the afternoon orbit. NOAA's JPSS will fly more instruments and capabilities in the afternoon orbit versus the early morning orbit, so the bulk of the work under the former program is shifting to NOAA's responsibility. Second, the cost estimates for NOAA under the restructured NPOESS program were performed at the 80% confidence level (as recommended by both the IRT and the FY2010 Omnibus Appropriations report language for NOAA), which results in a larger figure as compared to previous cost estimates. This confidence level provides NOAA and NASA the necessary resources to address technical risk and to meet the FY 2015 launch schedule.

The decision announced on February 1 directed NOAA, NASA, and DoD to restructure the means by which they cooperate to achieve the observational requirements from the operational polar-orbiting environmental satellites. The key elements of the restructured program will retain the observational requirements of the NPOESS program; however, NOAA, NASA, and DoD will be responsible for meeting these requirements through its assigned orbits.

NOAA's JPSS will maintain the observations that were planned for NPOESS in the afternoon orbit. JPSS will fly the Visible/Infrared Imager/Radiometer Suite (VIIRS), Cross-track Infrared Sounder (CrIS), Advanced Technology Microwave

Sounder (ATMS), and the Ozone Mapping and Profiler Suite (OMPS). JPSS will also fly instruments that are being procured with funds from the NOAA Climate Sensor Program - the Cloud and Earth Radiant Energy System (CERES)/Earth's Radiation Budget Sensor (ERBS) and the Total Solar and Spectral Irradiance Sensor (TSIS) instruments. The Microwave Imager/Sounder (MIS) will not fly in the afternoon orbit; however, NOAA remains interested in acquiring MIS-type observations and has initiated discussions with the Japan Aerospace Exploration Agency (JAXA) to collaborate in its Global Change Observation Mission (GCOM) missions. The GCOM's Advanced Microwave Scanning Radiometer (AMSR) instrument will satisfy some of the Key Performance Parameters that the MIS instrument would have supported and, along with the JPSS ATMS, will continue the legacy microwave capability in the afternoon orbit established by NOAA's Polar-orbiting Operational Environmental Satellite (POES) sounders and the AMSR on the NASA Earth Observing System (EOS) Aqua mission. Development of the Space Environment Monitor (SEM) instrument remains subject to completion of DoD's review of its requirements and analysis of alternatives to fulfill them. The JPSS program architecture maintains capability for SEM observations in the afternoon orbit.

NOAA, with NASA as its acquisition agent, and with input from DoD, has begun to develop a transition plan to ensure that the significant changes that have occurred as a result of restructuring the NPOESS program will not affect its ability to develop the satellites in the afternoon orbit. The transition of the program will take some time, and NOAA and NASA expect the work on the details of the full effort to be concluded by the Fall. NOAA will work to incorporate DoD's plans for its portion of the restructured program as soon as it is finalized.

10. What is the risk and the range of additional costs to NOAA related to the termination of the NPOESS program beyond those shown in the FY11 budget request?

Answer: The risk to NOAA from the NPOESS restructuring results from the possible termination of the current NPOESS contract. The purpose of the restructuring is to realign acquisition responsibilities to the agencies which have the mission requirements. That decision eliminates the Tri-Agency management structure that impeded direct mission accountability. The Agencies are currently in negotiations with the contractor, who has agreed to be supportive during this transition. There is the potential for some contract modification costs, and the FY2011 budget request already reflects the potential for these costs.

11. As a post-mortem on NPOESS, what would you identify as the characteristics that led to failure, and how does the new plan for NOAA's program specifically address those flaws?

Answer: The Independent Review Team (IRT) recognized that the major challenge of NPOESS was jointly executing the program between three agencies with differing technical objectives, acquisition procedures, engineering and management philosophies, risk tolerance, and approaches to managing budget adjustments. Trying to find common ground on a single program (with a single common platform and a uniform set of instruments) proved to be an extraordinarily difficult task. Because of these differing processes and objectives, the IRT concluded that the NPOESS program as constructed had little chance of success. The restructured program will resolve this challenge by splitting the procurements. The platforms for the respective orbits will be developed and procured so as to leverage off the strength of each agency, and also to best harness the experience each agency has in continuing and improving on legacy measurements. Each agency will take the appropriate acquisition planning and implementation actions to meet the needs for their respective orbits. The agencies will continue to partner in those areas that have been successful in the past, such as a shared ground system and operation of both morning and afternoon platforms by NOAA. The restructured programs will also eliminate the NPOESS tri-agency structure that has made management and oversight difficult, contributing to the poor performance of the program.

The IRT also noted that the NPOESS program was isolated from an acquisition center. The program also lacked timely access to technical expertise, broad mentoring and development opportunities for staff, and rigorous checks and balances of engineering and program processes. The Administration followed the recommendation of the IRT concerning alignment of the program with an established acquisition center -- in this case, NASA's Goddard Space Flight Center will be NOAA acquisition agent for the afternoon orbit, and the Air Force Space and Missile Center (SMC) will be DoD's acquisition agent for the early morning orbit.

Doubling Path for Basic Research Agencies

12. **Previous budget requests from this administration and the prior administration have proposed a 10 year doubling path for NSF, NIST and the Dept of Energy's Science program. This budget request pushes that goal to the right by one year, proposing to take 11 years to double those budgets. What is the rationale for doing so, and what conclusions should Congress draw about the relative priority of basic scientific research in the Federal budget?**

Answer: The Budget maintains the President's commitment to double funding for key science agencies. The 2011 Budget establishes a budget profile to achieve doubling by 2017. The President's Budget is committed to making dramatic reductions in the Federal budget deficit over the next several years. One part of that commitment is to freeze nonsecurity discretionary spending at 2010 enacted funding levels for three years. Within an overall nonsecurity discretionary spending freeze, the 2011 Budget proposes a 6.6 percent increase to $13.3 billion for these three agencies. To meet future deficit reduction goals the timetable for completing the doubling commitment has been shifted from 2016 to 2017.

Representative John A. Culberson
Questions for the Record

1. **In an effort to be transparent, I would like to know which NASA officials were consulted about the president's proposal to cancel the Constellation program. Please provide me with copies of any and all emails and correspondence between officials in the Office of Science and Technology Policy, NASA and the Office of Management and Budget, in which the Constellation program and/or the U.S. human spaceflight program was discussed.**

   Answer: The Committee to Review U.S. Human Spaceflight Plans consulted multiple NASA officials about the Constellation Program. Led by the distinguished aerospace engineer, Norman Augustine, this independent blue-ribbon panel conducted an intensive review of the program over a period of five months last year. NASA, OMB, and OSTP drew on the Augustine Federal Advisory Committee's findings for the President's consideration as he prepared his FY2011 budget proposal. The list of experts, including NASA experts and NASA Center directors, who provided input into that process, is available at www.nasa.gov/offices/hsf/home/index.html.

TUESDAY, MARCH 23, 2010.

NASA (NATIONAL AERONAUTICS AND SPACE ADMINISTRATION) FY2011 BUDGET OVERVIEW

WITNESS

MAJOR GENERAL CHARLES F. BOLDEN, JR., ADMINISTRATOR, NASA

CHAIRMAN'S OPENING REMARKS

Mr. MOLLOHAN. The hearing will come to order.

Mr. Wolf is at another hearing and he has asked that we move forward. And he should be here shortly.

Good afternoon. Welcome to this hearing of the Subcommittee on Commerce, Justice, and Science for fiscal year 2011. Today we will cover the budget status and future direction of the U.S. Space Program, and our witness is Retired Major General Charles F. Bolden, Jr., NASA Administrator.

Welcome, General Bolden.

In 1957, the Soviet Union shocked the world by launching Sputnik and challenged the U.S. with its superior capability. President Eisenhower responded by forming NASA. And by 1960, the U.S. had launched the first weather satellite, the first data relay satellite, and the first navigation satellite. The first commercial communications satellite, Telstar, was launched in July of 1962.

Confronting the Cold War challenge of the Soviet Union, President Kennedy said, "I believe this nation should commit itself to achieving the goal before this decade is out of landing a man on the moon and returning him safely to Earth. No single space project in this period will be more impressive to mankind or more important for the long-range exploration of space and none will be so difficult or expensive to accomplish."

In 1969, NASA delivered on his vision and U.S. superiority and technology, especially missile technology, was on clear display for all to see. The cost in today's dollars is almost a hundred billion dollars.

This amazing era of accomplishment continues to dominate the vision of NASA both within and without, but hard realities should be recognized. NASA employment peaked in 1967 and NASA pioneered reduction in force, RIF, procedures for the federal government. Over 10,000 people who had worked their hearts out getting us to the moon were out of job. NASA's budget peaked in 1966 at over 24 billion in today's dollars. Using Apollo Program capabilities, Skylab and Apollo-Soyuz flew. But from the summer of 1975 until the spring of 1981, the United States did not, could not fly an astronaut.

In answer to the question of what to do, President Nixon supported the start of the Space Shuttle Program. By the time it flew, the first U.S. Space Station had fallen to earth due to lack of funding and the resulting lack of capability to boost Skylab's orbit. The money was not made available to build a new orbiting lab as proposed, so the Shuttle had no orbiting lab to shuttle to except for the Russian Mir, which it visited multiple times.

In January of 1984, President Reagan challenged NASA to achieve a permanent man presence in space and the International Space Station Program began. The initial cost estimate was $8 billion and no one expected it to be 25 years and $40 billion before construction was complete.

In 1984, the Shuttles were new. No investment was begun to replace them until 2004—too late to prevent a gap in U.S. astronaut launch capability.

Today it is not the early 1960s. Then a trip to the moon was a science fiction dream. Today Star Wars and Star Trek are based on a dream of interstellar travel and galaxy-spanning federations or empires. In Kennedy's time, rocketry was a major hallmark of national technological achievement. Today U.S. achievement is evident in creation of the internet, invention of the iPhone, production of the fastest super computers, and sequencing of the human genome. The Soviet Union is no more. Our shooting wars are with those who oppose modernity, not those who challenge us in a rush to the future. Competition with China is more a matter of innovation, intellectual property, manufacturing, and resources.

In this contemporary context, faced with the need to set the future direction of the Human Spaceflight Program, the President has formulated a program that shifts from plowing ahead with new development programs driven by return to the moon to a focus on government development of new enabling technologies with the eventual goal of landing astronauts on Mars.

Exploration beyond low Earth orbit will be vigorous, but for a time, it will be achieved through the use of robots. Commercial provision of astronaut transport to the space station is proposed, and the life of the space station is extended until at least 2020. At the same time, NASA's programs in Earth and space science and aeronautics are strengthened. Education programs are continued, and the Kennedy launch complex is slated for modernization.

So today we find ourselves at another pivotal point for the Space Program. Like Presidents Nixon and Reagan, president Obama is committing the nation to human spaceflight as a continuing endeavor, but this commitment is part of a balanced effort within a constrained budget. Frankly, many of us yearn for the Apollo-like vision of the 1960s, but is that the approach that best serves our nation's interests?

Mr. Administrator, there is much we need to learn about this major change in the direction of our Space Program. Following my remarks, we invite you to summarize your testimony, which will be made a part of the record.

We just had a vote called. We have 12 minutes and 38 seconds to vote and I am going to invite you to make your remarks. Administrator Bolden.

ADMINISTRATOR BOLDEN'S OPENING REMARKS

General BOLDEN. Thank you, Mr. Chairman and Members of the Subcommittee. I thank you for the opportunity to appear today to discuss the President's FY 2011 budget request for NASA. I am grateful for the support and guidance of the Subcommittee and I look forward to working with you on enactment of the President's bold new direction for our Agency.

I want to say up front that I understand the Committee's concern that details, such as our justification documents, have been slow to reach you. I apologize and ask your attention to the details of this historic change in NASA's direction. Very soon, we will be announcing program office assignments needed to carry out the President's vision and challenges to NASA. Other details will become available in the coming weeks.

Since the introduction of the budget, many have asked what the destination is for human spaceflight beyond low-earth orbit under the President's plan. NASA's exploration efforts will focus not just on our moon but also on near-Earth asteroids, strategies, and the planet Mars and its moons. For me, the ultimate destination in our solar system at present is Mars. While we cannot provide a date certain for the first human visit with Mars, it is a key long-term destination. We can identify missing capabilities needed for such a mission and use this to help define many of the goals for our emerging technology development.

The right investments in technology will allow us to map out a realistic path to this destination and continues to inspire generations of school children, just as it inspired me many years ago. Growing up in Columbia, South Carolina and watching Buck Rogers go to Mars with ease each week from my seat in the balcony of a Carolina theater.

PRESIDENT'S BUDGET REQUEST

The President's fiscal year 2011 budget request for NASA is $19 billion, including an increase of $276 million over the enacted 2010 level. Longer term, I am pleased that the budget commits to an increased investment of $6 billion in NASA's science, aeronautics, and enabling technologies over the next five years compared with last year's budget. All of us at NASA appreciate the President making NASA such a high priority at a time when budget realities dictate reductions and freezes for other worthwhile programs.

With the President's new visions, the NASA budget will invest much more heavily on technology research and development than recent NASA budgets. This will foster new technological approaches, standards, and capabilities that are going to enable the next generation spaceflight, Earth-sensing and aeronautics capabilities.

These investments will produce additional opportunities for U.S. industry and spur new businesses such as a recently announced partnership between NASA and General Motors to build an advanced dexterous humanoid robot, R2.

CONSTELLATION PROGRAM TERMINATION

As the Constellation Program has ended in an orderly manner, I want to thank all of the NASA employees and contractors who have worked so hard on the program. Their commitment has brought great value to the Agency and to our Nation and they will continue to play a pivotal role in NASA's future path. Many of the things NASA has learned from the Constellation Program will be critical as the Agency moves forward.

However, as the Augustine Committee concluded, the Constellation Program is on an unsustainable trajectory. To continue on our current course, at best we will probably not be able to fly our astronauts to the moon until sometime after 2030. But to accomplish that task, we would have to make even deeper cuts to other parts of NASA's budget, terminating support of the International Space Station early, and reducing our science and aeronautics efforts. Further, we would have had no funding to advance the state-of-the-art in any of the technology areas we need to enable us to do the things in space.

The President's proposal to end Constellation enables us to present a fiscal year 2011 budget that includes: A flagship technology development and demonstration program with our international and commercial partners and other government entities, to demonstrate critical technologies, automated rendezvous and docking, and closed-loop life support systems. Heavy-lift research and development that will investigate a broad scope of research and development activities to support development, test, and ultimately flight of a heavy-lift launch vehicle sooner than projected for the Constellation Program as assessed by the Augustine Committee. Robotic precursor missions to multiple destinations in the solar system in support of future human exploration, including missions to the Moon, Mars, and its moons, Lagrange points, and near asteroids. Significant investments for the development of commercial, crew, and further cargo capabilities. In concert with our international partners, extension of the utilization of International Space Station to 2020 or beyond. Pursuit of cross-cutting space technology capabilities led by the newly established Office of the Chief Technologist, to spawn game-changing innovations to make space travel more affordable and sustainable. Climate change research and observations, which will enable NASA to substantially accelerate and expand its Earth science capabilities, including a replacement for the orbiting carbon observatory. Aeronautics research and development, including critical areas of Next Generation Air Transportation System or NextGen, green aviation and safe integration of unmanned aircraft systems into the national airspace. Education initiatives, including the recently announced Summer of Innovation Pilot Program to inspire middle-school students and better equip their teachers for improved classroom performance in STEM-related courses.

We understand that many concerns are being expressed about the budget, but I believe it is the right vision for NASA. I look forward to continued discussions with you and our authorizers about the concerns and how we might solve them.

Americans and people worldwide have turned to NASA for inspiration throughout our history—our work gives people an opportunity to imagine what is barely possible, and we at NASA get to turn their dreams into real achievements for all humankind through the missions we execute.

This budget gives NASA a roadmap to even more historic achievements as it spurs innovation, employs Americans in exciting jobs, and engages people around the world.

Mr. Chairman, thank you again for your support and that of this Subcommittee. I would be pleased to respond to any questions you or other members may have.

[The information follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
March 23, 2010

Statement of
Charles F. Bolden, Jr.
Administrator
National Aeronautics and Space Administration

before the

Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
U.S. House of Representatives

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear today to discuss the President's FY 2011 budget request for NASA. NASA is grateful for the support and guidance received from this Committee through the years and looks forward to working with you on enactment of the President's bold new direction.

The President's FY 2011 budget request for NASA is $19.0 billion, which represents an increase of $276.0 million above the amount provided for the Agency in the FY 2010 Consolidated Appropriations Act (P.L. 111-117), and an increased investment of $6.0 billion in NASA science, aeronautics, human spaceflight and enabling space technologies over the next five-years compared with last year's budget plan. Enclosure 1 displays the details of the President's FY 2011 budget request for NASA.

Before I discuss the details of the NASA budget request, I would like to talk in general about the President's new course for human exploration of space. With this budget, the United States has positioned itself to continue our space leadership for years to come.

The President's FY 2011 budget request is good for NASA because it sets the Agency on a sustainable path that is tightly linked to our Nation's interests. One measure of this is that it increases the Agency's top-line, in a time when many agencies have been flat or taken a cut. Even more, it reconnects NASA to the Nation's priorities – creating new high-tech jobs, driving technological innovation, and advancing space and climate science research. It puts the Agency back on track to being the big-picture innovator that carries the Nation forward on a tide of technological development that creates our future growth. We should make no mistake that these are the drivers for NASA's proposed budget increase of $6 billion dollars over the next five years.

At the highest level, the President and his staff, as well as my NASA senior leadership team, closely reviewed the Augustine Committee report, and we came to the same conclusion as the Committee: The Constellation program was on an unsustainable trajectory. And if we continue on that course, at best we would end up flying a handful of astronauts to the moon sometime after 2030. But to accomplish that task, we would have to make even deeper cuts to the other parts of NASA's budget, terminating support of the International Space Station (ISS) early and reducing our science and aeronautics efforts. Further, we would have no funding to advance the state of the art in any of the technology areas that we need to enable us to do new things in space, such as lowering the cost of access to space and developing closed-loop life support, advanced propulsion technology, and radiation protection. The President recognized that what was truly needed for beyond LEO exploration was game-changing technologies; making the fundamental investments that will provide the foundation for the next half-century of American leadership in space exploration. In doing so, the President put forward what I believe to be the most authentically visionary policy for real human space exploration that we have ever had. At the same time, under the new plan, we will ensure continuous American presence in space on the ISS throughout this entire decade, re-establish a robust and competitive American launch industry, start a major heavy lift R&D program years earlier, and build a real technological foundation for sustainable beyond-LEO exploration of our moon, near-Earth asteroids, Lagrange points, and ultimately Mars.

Now let me turn to describe the FY 2011 NASA budget request in detail.

Highlights of the FY 2011 Budget Request

The President has laid out a bold new path for NASA to become an engine of innovation, with an ambitious new space program that includes and inspires people around the world. Beginning in FY 2011, the United States will pursue a more sustainable and affordable approach to human space exploration through the development of transformative technologies and systems. As the Constellation Program is ended in an orderly manner, NASA will encourage the development of commercial human spaceflight vehicles to safely access low-Earth orbit and will develop new technologies that will lay the foundation for a more exciting, efficient and robust U.S. human exploration of the solar system than we are currently capable of, while further strengthening the skills of our workforce and our Nation in challenging technology areas. NASA will also invest increased resources in climate change research and observations; aeronautics research and development (R&D), including green aviation; space technology development of benefit across the entire space sector; and education with an emphasis on Science, Technology, Engineering and Mathematics (STEM) learning.

Here is a broad outline of the FY 2011 budget plan followed by more details. In FY 2011, NASA will undertake:

- Transformative technology development and demonstrations to pursue new approaches to human spaceflight exploration with more sustainable and advanced capabilities that will allow Americans to explore the Moon, Mars and other destinations. This effort will include a flagship demonstration program, with international partners, commercial and other government entities, to demonstrate critical technologies, such as in-orbit propellant transfer and storage, inflatable modules, automated/autonomous rendezvous and docking, closed-loop life support systems, and other next-generation capabilities. It will also include projects that are smaller and shorter-duration, which will demonstrate a broad range of key technologies, including *in-situ* resource utilization and advanced in-space propulsion.

- Heavy-lift propulsion research and development that will investigate a broad scope of R&D activities to support next-generation space launch propulsion technologies, with the aim of reducing costs and shortening development timeframes for future heavy-lift systems for human exploration.

- Robotic precursor missions to multiple destinations in the solar system in support of future human exploration, including missions to the Moon, Mars and its moons, Lagrange points, and nearby asteroids.

- Significant investments for the development of commercial crew and further cargo capabilities, building on the successful progress in the development of commercial cargo capabilities to-date. NASA will allocate these funds through competitive solicitations that support a range of higher- and lower-programmatic risk systems and system components, such as human rating of existing launch vehicles and development of new spacecraft that can ride on multiple launch vehicles.

- Extension of the lifetime of the International Space Station (ISS), likely to 2020 or beyond, in concert with our international partners, with investments in expanded ISS utilization through upgrades to both ground support and onboard systems and use of the ISS as a National Laboratory.

- Pursuit of cross-cutting Space Technology capabilities, led by the newly established Office of the Chief Technologist, which will fund advancements in next-generation technologies, to help improve the Nation's leadership in key research areas, enable far-term capabilities, and spawn game-changing innovations that can unlock new possibilities and make space activities more affordable and sustainable. A NASA focus on innovation and technology will enable new approaches to our current mission set and allow us to pursue entirely new missions for the Nation.

- Climate change research and observations, which will enable NASA to substantially accelerate and expand its Earth Science capabilities, including a replacement for the Orbiting Carbon Observatory, development of new satellites recommended by the National Academy of Sciences Decadal Survey, and development of smaller Venture class missions. This investment will ensure the critically important continuity of certain key climate measurements and enable new measurements to address unknowns in the climate system, yielding expanded understanding of our home planet and improved understanding of climate change.

- Aeronautics research and development, including critical areas of the Next Generation Air Transportation System, environmentally responsible aviation, and safe integration of unmanned aircraft systems into the national airspace.

- Education initiatives, including the recently announced Summer of Innovation pilot program involving NASA scientist and curricula to inspire middle-school students and their teachers with exciting experiences that spur those students to continue in STEM careers.

I wish to emphasize that NASA intends to work closely with the Congress, including this Committee, to make a smooth transition to the new Exploration program, called for in the President's request, working responsibly on behalf of the taxpayers. With my deepest gratitude, I commend the hard work and dedication that thousands of NASA and contractor workers have devoted to Constellation over the last several years. Their commitment has brought great value to the Agency and to our Nation, and they will continue to play a pivotal role in NASA's future path. Many of the things NASA has learned from the Constellation program will be critical as the Agency moves forward.

The following contains more detail on the summary points made above, in the standard budget order for NASA's appropriation accounts.

Science

The President's FY 2011 request for NASA includes $5,005.6 million for Science. The NASA Science Mission Directorate (SMD) continues to expand humanity's understanding of our Earth, our Sun, the solar system and the universe with 59 science missions in operation and 30 more in various stages of development. The Science budget funds these missions as well as the research of over 3,000 scientists and their students across our Nation. The recommendations of the National Academies/National Research Council (NRC) decadal surveys help to guide SMD in setting its priorities for strategic science missions; and SMD selects competed missions and research proposals based on open competition and peer review.

The FY 2011 budget request for Science includes $1,801.7 million for **Earth Science.** This request increases investment in Earth Science by $1.8 billion from FY 2011 to FY 2014 compared to the FY 2010 budget, for a more aggressive response to the challenge of climate change. NASA will rapidly develop an Orbiting Carbon Observatory-2 mission for launch early in 2013 and a GRACE Follow-On mission for launch in late 2015, respectively, to initiate and extend key global climate data sets. This request accelerates several high-priority Decadal Survey missions that will advance climate research and monitoring. The increased funding accelerates launch of the Soil Moisture Active/Passive (SMAP) mission by six months from its estimated date at the recent Agency Key Decision Point (KDP)-B review, to November 2014. ICESAT-2 is advanced by five months relative to the estimated date at its recent Agency KDP-A review, to October 2015. The Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission and the Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) mission are each accelerated by two years, with both launching in late 2017. Thus, the budget request allows all four Tier-1 Decadal Survey missions to be launched between 2014 and 2017. In addition, NASA—working with the U.S. Global Change Research Program—will be able to identify and begin development for accelerated launch of selected Tier-2 Decadal Survey missions focused on climate change. The budget supports critical continuity of climate observations, including a Stratospheric Aerosol and Gas Experiment III (SAGE III) instrument to be developed for deployment on the ISS, while also supporting an accelerated pace of smaller "Venture class" missions. Finally, increased resources for Earth Science will allow NASA to expand key mission-enabling activities, including carbon monitoring, technology development, modeling, geodetic ground network observations, and applications development including the highly successful SERVIR program.

At present, NASA Earth-observing satellites provide the bulk of the global environmental observations used for climate change research in the United States and abroad. This year, analyses of NASA satellite measurements quantified the rates of ground water depletion since 2003 in California and in India's Indus River valley—rates that are unsustainable for the future. NASA conducted the first ICEBridge airborne campaigns in both Arctic and the Antarctic, to maintain the critical ice measurements during the gap in time between the ICESAT-1 and -2 satellites.

In FY 2011, the Glory and Aquarius missions will launch; and FY 2011 should close with the launch of the NPOESS Preparatory Project. The Landsat Data Continuity Mission will complete spacecraft integration and test, the Operational Land Imager will be delivered, and the Thermal Infrared Sensor will continue development. The Global Precipitation Mission will complete its System Integration Review in preparation for the beginning of assembly, integration and testing. During FY 2011, the SMAP mission will transition from formulation to development, and ICESAT-2 will begin design. Also in FY 2011, instrument development and observations initiated under the first Venture class solicitation for sustained airborne missions will reach full funding, and the next Venture class solicitations will be released—this time for space-based mission instrument, and complete mission, developments. Engineering studies and focused, actively-managed technology investments – instruments, components, and information systems – continue for the suite of future missions recommended by the National Research Council (NRC) Decadal Survey. In FY 2011, the Earth Science Technology Program will make additional, competitively-selected, instrument technology investments to meet decadal survey measurement goals. Earth Science Research and Applied Sciences Programs will continue to employ satellite observations to advance the science of climate and environmental change, mitigation, and adaptation. NASA will demonstrate the use of Uninhabited Aerial Systems in field campaigns addressing atmospheric trace gas composition and hurricane genesis, and NASA's modeling and data analysis efforts will contribute to assessment activities of the Intergovernmental Panel in Climate Change and the U.S. Global Change Research Program.

The FY 2011 budget request for Science includes $1,485.8 million for **Planetary Science**. The current NASA planetary missions continue to make new discoveries and return fascinating images, including a previously unknown large and askew ring of Saturn and a near-complete map of the surface of Mercury. Mars continues to intrigue with signs of water ice just below the surface at mid-latitudes. The Mars rover Spirit is now an *in situ* science prospector, while Opportunity continues to roll toward the crater Endeavor. The Moon Mineralogy Mapper instrument on India's Chandrayaan-1 mission detected small amounts of water and hydroxyl molecules at unexpectedly low latitudes on the lunar surface. NASA selected three new candidate mission concepts for further study under the New Frontiers program, and will select the winning concept in FY 2011 to proceed to development. NASA will issue its next Discovery Announcement of Opportunity this year, and will select mission concepts and fund concept studies in FY 2011. NASA will also begin Advanced Stirling Radioisotope Generator development in FY 2011 to be available as an option to improve the performance of the radioisotope-fueled power sources for use in the next Discovery mission. The Mars Science Laboratory will complete development in FY 2011 for launch in fall 2011, beginning the most comprehensive astrobiology mission to the Red Planet to date. The MAVEN Mars aeronomy mission will continue development for launch in late 2013. NASA will establish a joint Mars Exploration Program with the European Space Agency (ESA) with a trace gas orbiter mission, including a European technology demonstration lander. In FY 2011, NASA plans to select instruments for the mission via a joint Announcement of Opportunity. To advance scientific exploration of the Moon, NASA will launch the GRAIL mission in late 2011 and continue development of LADEE for launch in 2013. Continuing its exploration of the outer planets, NASA will launch the Juno mission to Jupiter in August 2011. NASA will continue studies that support the possibility of a new major Outer Planets Mission concept pending the outcome of the NRC decadal survey now in progress, and will coordinate with ESA on a solicitation for science instruments. The new NRC Decadal Survey in Planetary Science should be complete in FY 2011. The FY 2011 budget request increases NASA's investment in identification and cataloging of Near Earth Objects and, with the Department of Energy, begins funding the capability to restart Plutonium-238 production here in the United States.

The FY 2011 budget request for Science includes $1.076.3 million for **Astrophysics**. The golden age of Astrophysics from space continues, with 14 observatories in operation. Astrophysics research, technology investments, and missions aim to understand how the universe works, how galaxies, stars and planets originated and developed over cosmic time, and whether Earth-like planets -- and possibly life -- exist elsewhere in the cosmos. The NASA Kepler telescope has discovered five exoplanets, ranging in size from Neptune to larger than Jupiter, demonstrating that the telescope is functioning as intended; additional discoveries are anticipated in the coming months and years. NASA's newest space observatory, WISE (Wide-Field Infrared Explorer), has captured its first look at the starry sky and its sky survey in infrared light has begun. Radio astronomers have uncovered 17 millisecond pulsars in our galaxy by studying unknown high-energy sources detected by the Fermi Gamma-ray Space Telescope.

The Hubble Space Telescope is operating at its peak performance thanks to the very successful servicing mission last year by the STS-125 crew. The Herschel and Planck missions, led by the European Space Agency with NASA as a partner, launched in 2009 and are returning remarkable scientific results. In FY 2011, NASA will complete most of the development of the NuSTAR mission and prepare it for launch. NASA will also begin developing the Gravity and Extreme Magnetism (GEMS) mission recently selected in the Explorer small satellite program. The James Webb Space Telescope (JWST) continues to make good progress in development toward a 2014 launch. Flight hardware for the many JWST subsystems is being designed, manufactured and tested, including the 18 segments of its 6.5-meter primary mirror; and the mission-level Critical Design Review for JWST will occur this spring. The SOFIA airborne observatory successfully conducted its first open-door flight test in December 2009—a major milestone toward the beginning of early science operations this year. The NRC is conducting a new Decadal Survey in astronomy and astrophysics, which will set priorities among future mission concepts across the full spectrum of Astrophysics, including dark energy, gravity wave, and planet-finding missions; the "Astro2010" Decadal Survey is expected in September.

The FY 2011 budget request for Science includes $641.9 million for **Heliophysics**. The Heliophysics operating satellites provide not only a steady stream of scientific data for the NASA research program, but also supply a significant fraction of critical space weather data used by other government agencies for support of commercial and defense activities in space. These data are used for operating satellites, optimization of power transmission networks, and supporting communications, aviation and navigation systems. The NASA Aeronomy of Ice in Mesosphere (AIM) satellite has provided the first comprehensive, global-scale view of the complex life cycle of Earth's highest clouds, Polar Mesospheric Clouds, finding clues to why they appear to be occurring at lower latitudes than ever before. The STEREO B spacecraft recently observed a sunspot behind the Sun's southeastern limb—before it could be seen from Earth. In a few days, this sunspot produced five Class M solar flares of the kind that disturb radio signals on Earth, signaling the end of the Sun's extended quiet period of recent years. The Solar Dynamic Observatory (SDO), launched on February 11, will provide images of the Sun of unprecedented resolution, yielding new understanding of the causes of solar variability and its impact on Earth. In FY 2011, the Radiation Belt Storm Probes mission will complete hardware manufacturing and begin integration and testing. The Solar Orbiter Collaboration with the European Space Agency will continue in formulation, and the Solar Probe Plus mission will undergo an initial confirmation review at the end of FY 2011. The Magnetospheric Multi-scale mission will continue development toward a Critical Design Review. IRIS, a recently selected small Explorer mission, will hold its Critical Design Review in FY 2011. The next Explorer Announcement of Opportunity will be released in 2010, with selection for Phase A studies in FY 2011. NASA is working with the NRC to arrange for the next decadal survey in Heliophysics.

Aeronautics Research

The U.S. commercial aviation enterprise is vital to the Nation's economic well being, directly or indirectly providing nearly one million Americans with jobs. In 2008 aerospace manufacturing provided the Nation with a trade surplus of over $57 billion. In the United States, more than 60 certified domestic carriers operate more than 28,000 flights daily, moving nearly one million travelers each day. We expect these flights to be safe, affordable, and convenient. We expect airlines to offer flights when and where we want to travel. In business and in our personal lives, the aviation industry is a key enabler to our way of life and the smooth functioning of our economy. However, the air transport system is near maximum capacity given today's procedures and equipment. Rising concerns about the environmental and noise impacts of aviation further limit future growth.

The FY 2011 budget request for Aeronautics is $579.6 million, an increase of $72.6 million, which will strongly support our existing portfolio of research and development to directly address these most critical needs of the Nation and enable timely development of the Next Generation Air Transportation System (NextGen). Through a balanced research and development portfolio, NASA's Aeronautics Research Mission Directorate (ARMD) is exploring early-stage innovative ideas, developing new technologies and operational procedures through foundational research, and demonstrating the potential of promising new vehicles, operations, and safety technology in relevant environments. Our goals are to expand capacity, enable fuel-efficient flight planning, reduce the overall environmental footprint of airplanes today and, in the future, reduce delays on the ground and in the sky, and improve the ability to operate in all weather conditions while maintaining the current high safety standards we demand.

The FY 2011 budget request for Aeronautics includes $228.5 million for the **Fundamental Aeronautics Program**, which seeks to continually improve technology that can be integrated into today's state-of-the art aircraft, while enabling game-changing new concepts such as Hybrid Wing Body (HWB) airframes which promise reduced drag (thus improving fuel burn) and open-rotor engines which offer the promise of 20 percent fuel burn reduction compared to today's best jet engines. In partnership with Boeing and the Air Force, NASA has completed over 75 flights of the X48B sub-scale HWB aircraft at Dryden Flight Research Center in the last two years to explore handling and control issues. NASA is partnering with General Electric and Boeing to evaluate performance and integration of new open-rotor engine concepts in propulsion wind tunnels at the Glenn Research Center. NASA is also addressing key challenges to enable new rotorcraft and supersonic aircraft, and conducting foundational research on flight at seven times the speed of sound. American Recovery and Reinvestment Act funds have enabled NASA to re-commission a full-scale airframe structural test facility and to improve wind tunnels at the Langley, Ames, and Glenn Research Centers that are needed to assess new concepts that hold the promise of significant reductions in aircraft weight and fuel consumption. In partnership with industry, NASA has just initiated the first new government-funded effort on low NOx combustors in 15 years. In FY 2011, NASA will invest $20.0 million to design, build, and demonstrate a new generation of aircraft engine combustors that will lower the emission of harmful nitrogen oxides by 50 percent compared with current combustors while ensuring compatibility with current and future alternative aviation fuels.

A key research goal is to develop synthetic and bio-derived alternatives to the petroleum-derived fuel that all jet aircraft have used for the last 60 years, but little is known about the emissions characteristics of these alternative fuels. In 2009, NASA led a team of eight partners from government agencies, industry, and academia in measuring emissions from an aircraft parked on the ground operating on various blends of synthetic and standard jet fuel. This team discovered that synthetic fuel blends can reduce particulate emissions by as much as 75 percent compared to conventional jet fuels, which would offer a major improvement in local air quality around airports. Using results from this and other research efforts, NASA has established a publicly-available database of fuel and emissions properties for 19 different fuels and will perform similar tests on biofuels as they become available.

The FY 2011 budget request for Aeronautics includes $82.2 million for **Airspace Systems**. The focus of this program is to develop improved air traffic management procedures, which will expand the capacity and reduce the environmental footprint of the air transportation system.. Using flight data from just the top 27 airports in the country, NASA systems analysis results indicate that nearly 400 million gallons of fuel could be saved each year if aircraft could climb to and descend from their cruising altitude without interruption. Another 200 million gallons could be saved from improved routing during the cruise phase of flight. Achievement of such operations requires that aircraft spacing in the air and on-time arrival and departure from the regions around our major airports be greatly improved. New satellite-based navigation aids such as the ADS-B system that the Federal Aviation Administration (FAA) is installing throughout the country can enable these improvements, but safe and efficient operational procedures must first be developed, validated, and certified for operational use. In 2009, NASA partnered with FAA, United Airlines, and Air Services Australia to validate pilot and controller procedures for a new concept originally developed by NASA that enables aircraft to safely conduct climbs and descents outside radar coverage in close proximity to nearby traffic. NASA also provided safety analyses needed for regulatory approval. The procedures benefit both airlines and the traveling public by providing long-haul oceanic flight with easier access to fuel-efficient, turbulence-free altitudes. United Airlines is expected to begin flying the oceanic in-trail procedures on revenue flights in May 2011.

The FY 2011 budget request for Aeronautics includes $113.1 million for the **Integrated Systems Research Program.** Begun in FY 2010, this program evaluates and selects the most promising "environmentally friendly" engine and airframe concepts emerging from our foundational research programs for integration at the systems level. In FY 2011, the program will test integrated systems in relevant environments to demonstrate that the combined benefits of these new concepts are in fact greater than the sum of their individual parts. Similarly, we are integrating and evaluating new operational concepts through real-world tests and virtual simulations. These efforts will facilitate the transition of new capabilities to manufacturers, airlines and the FAA, for the ultimate benefit of the flying public. In addition to strongly supporting our ongoing research portfolio, the FY 2011 budget request includes increased funding to expand our research in new priority areas identified through close consultation with industry, academia and other federal agencies. In FY 2011, NASA will initiate a $30 million targeted effort to address operational and safety issues related to the integration of unmanned aircraft systems into the National Airspace System and augment research and technology development efforts by $20 million, including grants and cooperative agreements, to support NASA's environmentally responsible aviation research.

The FY 2011 budget request for Aeronautics includes $79.3 million for the **Aviation Safety Program.** This program conducts research to insure that aircraft and operational procedures maintain the high level of safety which the American public has come to count on. Safety issues span aircraft operations, air traffic procedures, and environmental hazards and this program is supporting research and delivering results in all three areas. American carriers operate 6,500 aircraft on more than 28,000 flights daily. For most of the day the FAA is controlling more than 4,000 aircraft in the sky at the same time. Further increases in capacity will require increased levels of automation for command and control functions and to analyze vast amounts of data, as well as increased complexity of the overall system. It now costs more to prove today's flight-critical systems are safe than it does to design and build them. The Joint Planning and Development Office has identified Verification and Validation (V&V) of aviation flight-critical hardware and software systems as one of the major capability gaps in NextGen. Therefore in FY 2011, NASA is initiating a new $20 million research activity in V&V of aviation flight-critical systems to develop methodologies and concepts to effectively test, validate and certify software-based systems that will perform reliably, securely, and safely as intended.

NASA will continue to tackle difficult issues that threaten the safety of commercial flight, ranging from human/machine interaction to external hazards such as weather and icing, as the aircraft industry has come to rely on NASA expertise in predicting the effects of icing on aircraft performance at low and intermediate altitudes. However, over the last 10 years a new form of icing problem has surfaced, occurring primarily in equatorial regions at high cruise altitudes and causing engine power loss or flameout. These conditions cannot be duplicated in any existing ground test facility. To study this problem, in 2009 NASA initiated an effort to modify the Propulsion Systems Laboratory at the Glenn Research Center to enable research on ways to mitigate the effects of high-altitude icing and development of new engine certification procedures.

The FY 2011 budget request for Aeronautics includes $76.4 million for the **Aeronautics Test Program** (ATP), which makes strategic investments to ensure availability of national ground facilities and flight assets to meet the testing needs of NASA and the Nation. The program also invests in the development of new test instrumentation and test technologies. One such example is ATP's collaboration with the Aviation Safety Program to provide a new testing capability in the NASA-Glenn PSL facility to address the threat of high-altitude ice crystals to jet engine operability. The program recently demonstrated for the first time the ability to generate ice crystals at the very cold temperatures (-60 °F) encountered at commercial aircraft cruise altitudes. The PSL high-altitude ice crystal capability will become operational in FY 2011. The program also completed the development of a new Strategic Plan to provide the vision and leadership required to meet national goals; provide sustained support for workforce, capability improvements, and test technology development; and provide strategic planning, management, and coordination with NASA, government, and industry stakeholders. This plan will provide informed guidance as ATP develops a critical decision tool for building well-coordinated national testing capabilities in collaboration with the Department of Defense through the National Partnership for Aeronautical Testing (NPAT).

Partnerships with industry, academia, and other Federal agencies are critical to the success and relevance of NASA research. Through close collaboration, NASA ensures that it works on the right challenges and improving the transition of research results to users. NASA is using NASA/FAA Research Transition Teams (RTTs) to conduct joint research and field trials to speed acceptance of new air traffic management procedures. The Agency is also coordinating management and operation of the Federal government's large aeronautics ground test infrastructure through the NPAT. Through NASA Research Announcements (NRAs), NASA solicits new and innovative ideas from industry and academia while providing support for Science, Technology, Engineering, and Math departments. The Agency also funds undergraduate and graduate scholarships, Innovation in Aeronautics Instruction grants to improve teaching programs at the university level, and sponsor student design competitions at undergraduate and graduate levels for both U.S. and international entrants. By directly connecting students with NASA researchers and our industrial partners we become a stronger research organization while inspiring students to choose a career in the aerospace industry.

Exploration

The FY 2011 budget request for Exploration is $4,263.4 million, an increase of $483.6 million above the FY 2010 enacted level. Included in this budget request is funding for three new, robust programs that will expand the capabilities of future space explorers far beyond those we have today. NASA will embark on these transformative initiatives by partnering with the best in industry, academia and other government agencies, as well as with our international partners. These partners have been integral to much of NASA's previous success and are vital to our bold new vision.

NASA will encourage active public participation in our new exploration missions via a new participatory exploration initiative. Additionally, the FY 2011 budget request builds upon NASA's commercial cargo efforts by providing significant funding for the development of commercial human spaceflight vehicles, freeing NASA to focus on the forward-leaning work we need to accomplish for beyond-LEO missions. The FY 2011 budget request is a 40 percent increase over last year's investment in the Human Research Program, to help prepare for future human spaceflight exploration beyond low-Earth orbit. Lastly, the Exploration FY 2011 budget request includes funding for the Constellation Program close out activities spread across FY 2011 and FY 2012.

In the near term, NASA is continuing Constellation work to ensure an orderly closeout of the program in FY 2011 and to capture of all of the knowledge learned through its key efforts. The Constellation Program is focusing on completing its Preliminary Design Review (PDR), which will conclude this year. NASA believes that completing the Constellation PDR will support not only the close-out process for Constellation, but also will ensure that historical data from Constellation work is documented, preserved and made accessible to future designers of other next-generation U.S. human spaceflight systems.

The Exploration FY 2011 budget request includes three new robust research and development programs that will enable a renewed and reinvigorated effort for future crewed missions beyond low-Earth orbit:

- **Technology Development and Demonstration Program**: $652.4 million is requested in FY 2011, and a total of $7,800.0 million is included in the five year budget plan, to invent and demonstrate large-scale technologies and capabilities that are critical to future space exploration, including cryo-fluid management and transfer technologies; rendezvous and docking technologies; and closed-loop life support systems. These technologies are essential to making future exploration missions more capable, flexible, and affordable.

- **Heavy-Lift and Propulsion Research and Development Program:** $559.0 million is requested in FY 2011, and a total of $3,100.0 million is included in the five-year budget plan, for an aggressive, new heavy-lift and propulsion R&D program that will focus on development of new engines, propellants, materials and combustion processes that would increase our heavy-lift and other space propulsion capabilities and significantly lower operations costs – with the clear goal of taking us farther and faster into space consistent with safety and mission success.

- **Robotic Exploration Precursor Program**: $125.0 million is requested in FY 2011, and $3,000.0 million is included in the five-year budget plan, for robotic missions that will pave the way for later human exploration of the Moon, Mars and nearby asteroids. Like the highly successful Lunar Reconnaissance Orbiter and Lunar Crater Observation and Sensing Satellite missions that captured our attention last fall, future exploration precursor missions will scout locations and demonstrate technologies to locate the most interesting places to explore with humans and validate potential approaches to get them there safely and sustainably.

Cross-agency teams for each of these three areas are working to develop plans that delineate key areas for research and development, specify milestones for progress and set launch dates for relevant missions. They will report to the Administrator over the coming months, and the results of their efforts will be shared with the Congress when they are complete.

The Exploration FY 2011 budget request for **Commercial Spaceflight** is $812.0 million, which includes $500.0 million to spur the development of U.S. commercial human spaceflight vehicles, and a total of $6 billion in the five-year budget plan. This investment funds NASA to contract with industry to provide astronaut transportation to the International Space Station as soon as possible, reducing the risk of relying solely on foreign crew transports, and frees up NASA resources to focus on the difficult challenges in technology development, scientific discovery, and exploration. We also believe it will help to make space travel more accessible and more affordable. An enhanced U.S. commercial space industry will create new high-tech jobs, leverage private sector capabilities and energy in this area, and spawn other businesses and commercial opportunities, which will spur growth in our Nation's economy. And, a new generation of Americans will be inspired by these commercial ventures and the opportunities they will provide for additional visits to space. NASA plans to allocate this FY 2011 funding via competitive solicitations that support a range of activities such as human rating existing launch vehicles and developing new crew spacecraft that can ride on multiple launch vehicles. NASA will ensure that all commercial systems meet stringent human-rating and safety requirements before we allow any NASA crew member (including NASA contractors and NASA-sponsored International partners) to travel aboard a commercial vehicle on a NASA mission. Safety is, and always will be, NASA's first core value.

In addition to the $500 million identified for crew transportation development efforts, the budget also includes $312.0 million in FY 2011 for incentivizing NASA's current commercial cargo program. These funds--by adding or accelerating the achievement of already-planned milestones, and adding capabilities or tests--aim to expedite the pace of development of cargo flights to the ISS and improve program robustness.

Today, NASA is using $50.0 million from the American Recovery and Reinvestment Act of 2009 to help drive the beginnings of a commercial crew transportation industry. Through an open competition, in early February, NASA awarded Space Act Agreements to five companies who proposed ideas and concepts intended to make commercial crew services a reality. While there are many vibrant companies out there that we hope to partner with in the future, these five companies, along with our two currently funded Commercial Orbital Transportation Services partners (Space Exploration Technologies and Orbital Sciences Corporation) are at the forefront of a grand new era in space exploration.

The Exploration FY 2011 budget request includes $215.0 million for the **Human Research Program**, an increase of more than 40 percent over the FY 2010 enacted level, and an investment of $1,075 million over the five-year budget plan. The Human Research Program is a critical element of the NASA human spaceflight program in that it develops and validates technologies that serve to reduce medical risks associated for crew members.

The Exploration FY 2011 budget request includes $1,900.0 million for **Constellation Closeout** requirements, and a total of $2,500.0 million over the FY 2011-2012 timeframe. These funds will be used for related facility and close-out costs, potentially including increased costs for Shuttle transition and retirement due to Constellation cancellation. The Agency has established senior planning teams to outline options for Constellation close out expeditiously and thoughtfully and to assess workforce, procurement and other issues, which will report to the Administrator over the coming months, to ensure that people and facilities are best utilized to meet the needs of NASA's new missions. NASA will work closely with the Congress as these activities progress.

NASA recognizes that this change will personally affect thousands of NASA civil servants and contractors who have worked countless hours, often under difficult circumstances, to make the Constellation Program successful. I commend the investment that these dedicated Americans have made and will continue to make in our Nation's human spaceflight program. Civil servants who support Constellation should feel secure that NASA has exciting and meaningful work for them to accomplish after Constellation, and our contractor colleagues should know that NASA is working expeditiously to identify new opportunities for them to partner with the Agency on the new Exploration portfolio.

Space Technology

Through the new Space Technology Program, led by the recently established Office of the Chief Technologist, NASA will increase its support for research in advanced space systems concepts and game-changing technologies, enabling new approaches to our current mission set and allowing the pursuit of entirely new missions. Using a wide array of management, funding, and partnership mechanisms, this program will engage the brightest minds in private industry, across the NASA Centers, and throughout academia. This new program builds upon the success of NASA's Innovative Partnerships Program and directly responds to input from multiple NRC reports, as well as the Augustine Committee. The Space Technology program will meet NASA's needs for new technologies to support future NASA missions in science and exploration, as well as the needs of other government agencies and the Nation's space industry in a manner similar to the way NACA aided the early aeronautics industry. Many positive outcomes are likely from a long-term NASA advanced space systems concepts and technology development program, including a more vital and productive space future than our country has today, a means to focus NASA intellectual capital on significant national challenges and needs, a spark to renew the nation's technology-based economy, an international symbol of our country's scientific and technological leadership, and a motivation for many of the country's best young minds to enter into educational programs and careers in engineering and science.

The FY 2011 budget request for Space Technology is $572.2 million, and $4,925.9 million is included in the five-year budget plan. With this initiative, NASA will expand its Technology and Innovation portfolio to include: open competitions to stimulate highly innovative, early-stage space system concepts and ideas; development of technologies that can provide game-changing innovations to address NASA and national needs; and development and infusion of cross-cutting capabilities into missions that address needs from multiple NASA Mission Directorates, other government agencies, and commercial activities in space, while fostering and stimulating a research and development culture at NASA Centers. Beginning in FY 2011, activities associated with the Innovative Partnerships Program are transferred to Space Technology.

The need for advanced capabilities is increasing as NASA envisions missions of increasing complexity to explore and understand the Earth, our solar system, and the universe. Technology and innovation are critical to successfully accomplishing these missions in an affordable manner. The Space Technology program will enhance NASA's efforts to nurture new technologies and novel ideas that can revolutionize our aerospace industrial base, as well as to address national and global challenges and enable whole new capabilities in science and exploration that will be of benefit to the Nation. Key focus areas include communications, sensors, robotics, materials, and propulsion. The Space Technology program will use open competitions such as NASA Research Announcements and Announcements of Opportunity, targeted competitions such as those for small business (SBIR), universities (STTR), and engage early career scientists and engineers. NASA will also continue to use challenges and prizes to stimulate innovative new approaches to technology development and will encourage partnerships with both established and emerging commercial space industries. Through the three major elements of this program--Early-Stage Innovation, Game-Changing Innovation, and Crosscutting Capabilities--a broad suite of management, funding and partnership mechanisms are employed to stimulate innovation across NASA, industry and academia.

The Early-Stage Innovation program element sponsors a wide range of advanced space system concept and initial technology development efforts across academia, industry and the NASA Centers. This program element includes: (a) the Space Technology Research Grant program (analogous to the Fundamental Aeronautics program within NASA's Aeronautics Research Mission Directorate) that focuses on foundational research in advanced space systems and space technology, (b) re-establishment of a NIAC-like Program to engage innovators within and external to the Agency in accordance with the recommendations of the NRC's *Fostering Visions of the Future* report, (c) enhancement of the Innovative Partnership Programs Seed Fund into a Center Innovations Fund to stimulate aerospace creativity and innovation at the NASA field Centers, (d) NASA's SBIR/STTR program to engage small businesses, and (e) the Centennial Challenges Prize Program to address key technology needs with new sources of innovation outside the traditional aerospace community. Competitive selection is a major tenet of all the activities within this low technology readiness level (TRL) program element.

The Game Changing Innovation program element focuses on maturing advanced technologies that may lead to entirely new approaches for the Agency's future space missions and solutions to significant national needs. Responsive to the NRC report, *America's Future in Space: Aligning the Civil Space Program with National Needs*, this program element demonstrates the feasibility of early-stage ideas that have the potential to revolutionize future space missions. Fixed-duration awards are made to PI-led teams comprised of government, academia and industry partners. These awards are evaluated annually for progress against baseline milestones with the objective of maturing technologies through ground-based testing and laboratory experimentation. NASA intends to draw from DARPA's experience to create and implement collaborative game-changing space technology initiatives. New technologies considered may include advanced lightweight structures and materials, advanced propulsion, power generation, energy storage and high bandwidth communications. With a focus on such potentially revolutionary technologies, success is not expected with each investment; however, on the whole, and over time, dramatic advances in space technology enabling entirely new NASA missions and potential solutions to a wide variety of our society's grand technological challenges are anticipated.

A Crosscutting Capabilities program element matures a small number of technologies that are of benefit to multiple customers to flight readiness status. Technical risk, technology maturity, mission risk, customer interest, and proposed cost are discriminators planned for use in the selection process. For infusion purposes, proposing teams are required to have a sponsor willing to cost share a minimum of 25 percent of the planned development effort. With objectives analogous to the former New Millennium program, NASA will pursue flight demonstrations not only as standalone missions, but also as missions of opportunity on planned NASA missions as well as international and commercial space platforms. The Commercial Reusable Suborbital Research Program (which provides suborbital flight opportunities for technology demonstrations, scientific research and education), the Facilitated Access to the Space environment for Technology (FAST) project (which focuses on testing technologies on parabolic aircraft flights that can simulate microgravity and reduced gravity environments) and the Edison Small Satellite Demonstration Missions project (which develops and operates small satellite missions in partnership with academia). are also included in this program element.

NASA has had past success in the development of game-changing technologies and the transfer of its products and intellectual capital to industry. As an example, consider the Mars Pathfinder mission of the early 1990s. In addition to accomplishing its science and technology objectives, Mars Pathfinder established surface mobility and ground truth as important exploration principles, created a groundswell of interest and a foundational experience for a new generation of Mars scientists and engineers, re-engaged the public with Mars as a destination worthy of exploration, led to the creation of NASA's Mars program and establishment of a Mars program budget line, and led to a wide spectrum of small missions to Mars, the asteroids, comets and other bodies in our solar system. For NASA's robotic exploration program, Mars Pathfinder was clearly a game-changer. In a more recent example, consider NASA's recent improvements to thermal protection system (TPS) materials through an Advanced Capabilities development project. Over three years, a NASA-industry team raised the TRL of 8 different TPS materials from 5 different commercial vendors, eventually selecting the best as the system for the Orion heat shield. In addition to providing a heat shield material and design for Orion on time and on budget, this Advanced Capabilities development project re-invigorated a niche space industry that was in danger of collapse, re-established a NASA competency able to respond to future TPS needs. For example, the team identified a potentially catastrophic problem with the planned MSL heat shield and remedied the problem by providing a viable alternate heat shield material and design within stringent schedule constraints. The mature heat shield material and designs have been successfully transferred to the commercial space industry, including the TPS solution for the SpaceX Dragon capsule. Beginning in FY 2011, the new NASA Space Technology program aims to strengthen and broaden these successful innovation examples across a wide range of NASA enterprises and significant national needs.

Space Operations

The FY 2011 budget request includes $4,887.8 million for Space Operations, funding the Space Shuttle program, the International Space Station Program, and the Space and Flight Support program.

The FY 2011 budget request for the **Space Shuttle** program is $989.1 million. In 2009, the Space Shuttle flew five times, delivering to the ISS its final set of solar arrays and the equipment needed to support a six-person permanent crew; servicing the Hubble Space Telescope; completing the assembly of the three-module Japanese Kibo science laboratory; outfitting the Station with two external payload and logistics carriers, the Materials Science Research Rack-1, the Fluid Integrated Rack, the Minus Eighty-Degree Laboratory Freezer, a treadmill, and air revitalization equipment; and, delivering key supplies.

In 2010, the Shuttle is slated to fly out its remaining four missions, including the recently completed STS-130 mission. In April, Shuttle Discovery will carry up critical supplies for the ISS using a Multi-Purpose Logistics Module (MPLM) and the Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC). Atlantis will launch in May with the Russian Mini-Research Module-1, as well as the Integrated

Cargo Carrier - Vertical Light Deployment (ICC-VLD). This summer, Endeavour will carry the Alpha Magnetic Spectrometer (AMS) and attach it to the Station's truss structure. The AMS is a particle physics experiment, which will use the unique environment of space to advance knowledge of the universe and contribute to understanding the universe's origin. AMS is presently undergoing critical thermal and electrical testing at the European test facilities in the Netherlands. If these tests are successful, AMS will ship to KSC in May for the July launch. The final Shuttle mission, STS-133, is targeted for September of this year. Discovery will carry supplies to ISS, as well as an MPLM that will be installed on ISS as a permanent module, expanding the Station's storage volume. This flight will mark the completion of ISS assembly.

For almost 30 years, the Space Shuttle has carried U.S. and international astronauts into orbit; played a key role in the construction, outfitting, and resupply of the ISS; serviced the Hubble Space Telescope five times; served as an Earth-orbiting laboratory through the Spacelab and SpaceHab missions; and deployed a diverse array of payloads, including science probes and research experiments (such as the Magellan mission to Venus and Earth-orbiting tether experiments), communications satellites; and even student projects. NASA recognizes the role the Space Shuttle vehicles and personnel have played in the history of space activity, and looks forward to transitioning key workforce, technology, facilities, and operational experience to a new generation of human spaceflight exploration activities.

FY 2011 will be the first full year of major Space Shuttle Program (SSP) transition and retirement (T&R) activities. T&R is focused on the retirement of the SSP and the efficient transition of assets to other uses once they are no longer needed for safe mission execution. These activities include identifying, processing, and safing hazardous materials, and the transfer or disposal of SSP assets, including the preparation of Orbiters and other flight hardware for public display. T&R also covers severance and retention costs associated with managing the drawdown of the SSP workforce.

A key element of America's future in space is the **International Space Station**. The FY 2011 budget request for the International Space Station Program is $2,779.9 million. As of May 2009, the ISS has been able to support a six-person permanent crew, and during the STS-127 mission last July, the Station hosted 13 astronauts representing the five space agencies in the ISS partnership, including those of the United States, Russia, Japan, Europe and Canada. The three major science labs aboard ISS were completed in 2009 with the delivery of the Exposed Facility of the Japanese Kibo module. In addition, the first flight of Japan's H-II Transfer Vehicle (HTV) was successfully carried out last fall, adding a new cargo-carrying spacecraft to the fleet.

This year will mark the completion of assembly of the ISS – the largest crewed spacecraft ever assembled, measuring 243 by 356 feet, with a habitable volume of over 30,000 cubic feet and a mass of 846,000 pounds, and powered by arrays which generate over 700,000 kilowatt-hours per year. The ISS represents a unique research capability aboard which the United States and its partner nations can conduct a wide variety of research in biology, chemistry, physics and engineering fields which will help us better understand how to keep astronauts healthy and productive on long-duration space missions. Funding for ISS research is also reflected in the Exploration budget request and in the Space Technology budget request.

The FY 2011 budget request includes a dramatic increase in the Nation's investment in the research and capabilities of the ISS. With this investment, NASA will be able to fully utilize the ISS and increase those capabilities through upgrades to both ground support and onboard systems. Importantly, this Budget extends operations of the ISS, likely to 2020 or beyond. This budget makes a strong commitment to continued and expanded operation of the ISS. The United States as leader in space made this first step and will now work with the other ISS international partners to continue International operation of the ISS. ISS can inspire and provide a unique research platform for people worldwide.

ISS research is anticipated to have terrestrial applications in areas such as biotechnology, bioengineering, medicine and therapeutic treatment. The FY 2011 budget request for ISS reflects increased funding to support the ISS as a National Laboratory in which this latter type of research can be conducted. NASA has two MOUs with other U.S. government agencies, and five agreements with non-government organizations to conduct research aboard the ISS. NASA intends to continue to expand the community of National Laboratory users of the ISS. This budget request supports both an increase in research and funding for cargo transportation services to deliver experiments to the Station.

ISS can also play a key role in the demonstrations and engineering research associated with exploration. Propellant storage and transfer, life support systems, and inflatable technology can all benefit by using the unique research capabilities of ISS.

In addition to supporting a variety of research and development efforts, the ISS will serve as an incubator for the growth of the low-Earth orbit space economy. NASA is counting on its Commercial Resupply Services (CRS) suppliers to carry cargo to maintain the Station. The first CRS cargo flights will begin as early as 2011. It is hoped that these capabilities, initially developed to serve Station, may find other customers as well, and encourage the development of further space capabilities and applications. The suppliers involved will gain valuable experience in the development and operation of vehicles that can: 1) fly to the ISS orbit; 2) operate in close proximity to the ISS and other docked vehicles; 3) dock to ISS; and, 4) remain docked for extended periods of time.

As a tool for expanding knowledge of the world around us; advancing technology; serving as an impetus for the development of the commercial space sector; demonstrating the feasibility of a complex, long-term, international effort; and, perhaps most importantly, inspiring the next generation to pursue careers in science, technology, engineering, and mathematics, the ISS is without equal.

The FY 2011 budget request for **Space and Flight Support** (SFS) is $1,119.0 million. The budget request provided for critical infrastructure indispensable to the Nation's access and use of space, including Space Communications and Navigation (SCaN), the Launch Services Program (LSP), Rocket Propulsion Testing (RPT), and Human Space Flight Operations (HSFO). The SFS budget also includes a new and significant investment in the 21st Century Space Launch Complex, intended to increase operational efficiency and reduce launch costs by modernizing the Florida launch capabilities for a variety of NASA missions, which will also benefit non-NASA users.

In FY 2011, the SCaN Program will begin efforts to improve the robustness of the Deep Space Network (DSN) by initializing the replacement of the aging 70m antenna capability with the procurement of a 34m antenna. The NASA DSN is an international network of antennas that supports interplanetary spacecraft missions and radio and radar astronomy observations for the exploration of the solar system and the universe. The DSN also supports selected Earth-orbiting missions. In the third quarter, a System Requirements Review (SRR) of the Space Network Ground Segment Sustainment (SGSS) Project will be conducted, and the Program will have begun integration and testing of the Tracking and Data Relay Satellites (TDRS) K&L. In the area of technology, the Communication Navigation and Networking Reconfigurable Testbed (CoNNeCT) will be installed on ISS. This test bed will become NASA's orbiting SCaN laboratory on the ISS and will validate new flexible technology to enable greater spacecraft productivity. NASA will also have its first optical communication system ready for integration into the Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft. In addition, the Disruption Tolerant Networking (DTN) protocols will complete their development at the end of FY 2011 and should be ready for operations throughout the solar system. The SCaN operational networks will continue to provide an unprecedented level of communications and tracking services to over 75 spacecraft and launch vehicles during FY 2011.

The LSP has five planned NASA launches in FY 2011 including Glory, Aquarius, Juno, NPOESS Preparatory Project (NPP) and the Gravity Recovery and Interior Laboratory (GRAIL) mission. In addition to processing, mission analysis, spacecraft integration and launch services, LSP will continue to provide support for the development and certification of emerging launch services.

The RPT Program will continue to provide test facility management, and provide maintenance, sustaining engineering, operations, and facility modernization projects necessary to keep the test-related facilities in the appropriate state of operational readiness. These facilities will support many of the tests planned under ESMD's propulsion research program.

HSFO includes Crew Health and Safety (CHS) and Space Flight Crew Operations (SFCO). SFCO will continue to provide trained crew for the manifested Space Shuttle requirements, four ISS long-duration crew rotation missions. CHS will identify and deliver necessary core medical capabilities for astronauts. In addition, CHS will gather astronaut medical data critical for determining medical risk as a result of space flight and how best to mitigate that risk.

The 21st Century Launch Complex initiative will primarily benefit NASA's current and future operations at the Kennedy Space Center (KSC), but will also help to improve KSC launch operations for future and current non-NASA users of the range, with the goal of transforming KSC into a modern facility. This new initiative focuses on upgrades to the Florida launch range, expanding capabilities to support commercial launch providers, such as commercial cargo flights and future commercial crew flights in support of ISS, and expendable launch vehicles in support of the Science mission directorate payloads and robotic precursor missions. Additional areas under consideration include modernization activities to support safer and more efficient launch operations; enhancing payload processing capabilities through capacity increases, improvement, and modernization, in addition to potentially relocating the KSC perimeter where appropriate and feasible, to enable certain existing private sector facilities to lie outside the security perimeter, thus making it far more convenient to use those facilities; environmental remediation to reduce the impact on the surrounding areas; and supporting the modernization of the launch range capabilities. We will fully coordinate this activity with all users of the range.

Education

The FY 2011 budget request for Education is $145.8 million. This budget request furthers NASA's commitment to inspiring the next generation of explorers in the STEM disciplines. In FY 2011, NASA will continue to strongly support the Administration's STEM priorities and will continue to capitalize on the excitement of NASA's mission to stimulate innovative solutions, approaches, and tools that inspire student and educator interest and proficiency in STEM disciplines. This strategy will increase the distribution and impact of NASA progressive opportunities for elementary and secondary teachers, university faculty, students of all ages, and the public.

In FY 2011, NASA will support the Administration's STEM education teaching and learning improvement efforts, including Race to the Top and Educate to Innovate, while continuing efforts to incorporate NASA content into the STEM education initiatives of other federal agencies. This summer, NASA will launch *Summer of Innovation*, an intensive STEM teaching and learning program targeted at the middle school level that includes follow-on activities during the school year. NASA content and products will be incorporated into evidence-based summer learning programs across participating states with the goal of improving student academic performance and motivating them to pursue further education and successful careers. The FY 2011 request includes funding for *Summer of Innovation* over a three-year period.

NASA will also continue to partner with academic institutions, professional education associations, industry, and other Government agencies to provide K-12 teachers and university faculty with the experiences that capitalize on the excitement of NASA discoveries to spark their student's interest and involvement. Examples of such experiences are the NASA student launch initiatives and other hands-on payload development and engineering opportunities. The FY 2011 budget request also places increased emphasis on Education and cyber-learning opportunities and expands teacher pre-service, professional development and training programs. Additionally, NASA seeks to prepare high school students for undergraduate STEM study through experiences that blend NASA research and engineering experiences with classroom study and mentoring. Another Agency education goal is to broaden community college participation in NASA research and STEM workforce development.

In FY 2011, the Agency aims to increase both the use of NASA resources and the availability of opportunities to a diverse audience of educators and students, including women, minorities, and persons with disabilities. An example is the Innovations in Global Climate Change Education project that will be implemented within the Minority University Research and Education Program. The project will seek innovative approaches to providing opportunities for students and teachers to conduct research using NASA data sets to inspire achievement and improve teaching and learning in the area of global climate change.

Cross-Agency Support

NASA Cross-Agency Support provides critical mission support activities that are necessary to ensure the efficient and effective operation and administration of the Agency. These important functions align and sustain institutional and program capabilities to support NASA missions by leveraging resources to meet mission needs, establishing Agency-wide capabilities, and providing institutional checks and balances. Cross-Agency Support includes two themes: Center Management and Operations and Agency Management and Operations. The FY 2011 budget request includes $3,310.2 million for Cross Agency Support.

NASA's FY 2011 budget request includes $2,269.9 million for **Center Management and Operations,** which funds the critical ongoing management, operations, and maintenance of nine NASA Centers and major component facilities. NASA Centers continue to provide high-quality support and the technical talent for the execution of programs and projects.

NASA's FY 2011 budget request includes $1,040.3 million for **Agency Management and Operations**, which_funds the critical management and oversight of Agency missions, programs and functions, and performance of NASA-wide activities, including five programs: Agency Management, Safety and Mission Success, Agency Information Technology Services, and Strategic Capabilities Assets Program. Beginning in FY 2011, activities associated with the Innovative Partnerships Program are transferred to the Space Technology program. The FY 2011 budget request provides:

- $428.1 million for **Agency Management**, which supports executive-based, Agency-level functional and administrative management requirements. Agency Management provides for the operational costs of Headquarters as an installation; institutional and management requirements for multiple Agency functions; assessment and evaluation of NASA program and mission performance; strategic planning; and independent technical assessments of Agency programs.

- $201.6 million for **Safety and Mission Success** activities required to continue strengthening the workforce, training, and strengthening the fundamental and robust checks and balances applied on the execution of NASA's mission, and to improve the likelihood for safety and mission success for NASA's programs, projects, and operations. The engineering, safety and mission assurance, health and medical independent oversight, and technical authority components are essential to NASA's success and were established or modified in direct response to many of the key *Challenger* and *Columbia* accident board recommendations for reducing the likelihood for future accidents. Included under Safety and Mission Success is the Software Independent Verification and Validation program.

- $177.8 million for **Agency Information Technology Services**, which encompasses cross-cutting services and initiatives in IT management, applications, and infrastructure necessary to enable the NASA Mission and improve security, integration and efficiency of Agency operations. NASA plans significant emphasis on continued implementation of five major Agency-wide procurements to achieve the following: (1) consolidation of IT networks leading to improved network management, (2) consolidation of desktop/laptop computer services and mobile devices to improve end-user services, (3) data center consolidation to provide more cost-effective services, (4) Agency public web site management to improve access to NASA data and information by the public, and (5) Agency business systems development and maintenance to provide more efficient and effective business systems. NASA will also continue to improve security incident detection, response, and management through the Security Operations Center.

- $29.8 million for the **Strategic Capabilities Assets Program** (SCAP). This program funds the costs required to sustain key Agency test capabilities and assets, such as an array of flight simulators, thermal vacuum chambers, and arc jets, to ensure mission success. SCAP ensures that assets and capabilities deemed vital to NASA's current and future success are sustained in order to serve Agency and national needs. All assets and capabilities identified for sustainment either have validated mission requirements or have been identified as potentially required for future missions.

Construction and Environmental Compliance and Restoration

NASA Construction and Environmental Compliance and Restoration provides for the design and execution of all facilities construction projects, including discrete and minor revitalization projects, demolition for closed facilities, and environmental compliance and restoration. The FY 2011 budget request includes $397.4 million for Construction and Environmental Restoration, made up of:

- $335.3 million for the **Construction of Facilities** (CoF) Program, which funds capital repairs and improvements to ensure that facilities critical to achieving NASA's space and aeronautics program are safe, secure, environmentally sound, and operate efficiently. The Agency continues to place emphasis on achieving a sustainable and energy-efficient infrastructure by replacing old, inefficient, deteriorated building with new, efficient, high performance buildings that will meet NASA's mission needs while reducing future operating costs.

- $62.1 million for **Environmental Compliance and Restoration** (ECR) Program, which supports the ongoing cleanup of current or former sites where NASA operations have contributed to environmental problems. The ECR Program prioritizes these efforts to ensure that human health and the environment are protected for future missions. This program also supports strategic investments in environmental methods and practices aimed at reducing NASA's environmental footprint and lowering the risks of future cleanups.

Conclusion

Americans and people worldwide have turned to NASA for inspiration throughout our history – our work gives people an opportunity to imagine what is barely possible, and we at NASA get to turn those dreams into real achievements for all humankind. This budget gives NASA a roadmap to even more historic achievements as it spurs innovation, employs Americans in fulfilling jobs, and engages people around the world as we enter an exciting new era in space. NASA looks forward to working with the Subcommittee on implementation of the FY 2011 budget request.

Mr. Chairman, thank you for your support and that of this Subcommittee. I would be pleased to respond to any questions you or the other Members of the Subcommittee may have.

ASTRONAUT HEALTH RISK

Mr. MOLLOHAN. Thank you, Administrator Bolden.

Let me let the Subcommittee's members know we are into a vote where we have five minutes, five and a half minutes left for the vote, 386 members yet to vote. I intend to begin my questioning. We will recess during the vote and then come back and continue.

Thank you.

In testimony last month, you stated that today you could not in good conscience send astronauts to Mars given available technology. What health risks confront astronauts as they venture beyond low Earth orbit?

General BOLDEN. Mr. Chairman, the primary health risk is radiation exposure. Secondarily is just the long duration spaceflight with less than one G. But the radiation is the long pole in the tent. It is the one we do not know how to overcome just yet.

Mr. MOLLOHAN. To what extent do these risks pertain equally to flights to the moon, to asteroids, to Lagrange points, to Mars?

General BOLDEN. To most of the flights in the near Earth area such as the Moon, the exposure is not as long as it is going to Mars. The trip to Mars today is about eight months. It is significantly outside the Earth/Moon system and so the exposure to radiation is longer and more intense. A trip to the moon is two, three days, and so we do not find ourselves confronted by that threat as much.

Mr. MOLLOHAN. What technologies are needed to enable astronauts to survive missions to asteroids and Mars?

General BOLDEN. If I had the ability to snap my finger and do two things, I would develop much more capable in-space propulsion systems that would cut the travel time, the transit time from Earth to Mars at least in half and more, if possible. The second thing I would do would be to find some material that can sufficiently shield orbiting or transiting crew/members from the threat of radiation without adding untenable weight to the vehicle.

CONSTELLATION PROGRAM CANCELLATION

Mr. MOLLOHAN. The President's budget request is predicated on the cancellation of the Constellation Program. Why is this drastic step proposed?

General BOLDEN. Sir, there are a number of reasons for the cancellation of the Constellation Program and it has nothing to do with the people in the program who are exceptional engineers, scientists, and researchers. But it has a lot to do with the status of the program. When I became the Administrator, we were severely behind schedule and significantly over the amount of money that it would take to complete it. I think by the Augustine Committee's estimate, it probably would have taken another $45 to $60 billion dollars to complete it. In order to invest money in research and development that would enable us to get vehicles to put people on the surface of the moon or to transit to mars, the Constellation Program would have pretty much sucked up all of the funds that we could have used for research and development. So for a number of different reasons, it was not the right path for us to take. It was on an unsustainable path.

Mr. MOLLOHAN. Well, billions have been invested in Constellation.

General BOLDEN. Sir——

Mr. MOLLOHAN. Is that a waste or are we wasting billions?

General BOLDEN. Sir, we invested good money in Constellation and we have received incredible returns. When I look at some of the technologies that come out of the Constellation Program, and it is everything from just the way we process vehicles or the way we would process vehicles, some of the technologies like the robotics I mentioned, R2, the dexterous robot, that is a part of the Technology Demonstration Program that was a part of Constellation.

A lot of the human research that we do today, actually some of the research that is conducted on the International Space Station comes from expenditures that were a part of the Constellation Program trying to help us find better ways for humans to survive the trips that they were going to have to make, Rovers that are present that we could use today to go to the moon which have changed my mind about the need for permanent habitats. While not a direct part of the Constellation Program when it started, the funding for the Rovers and the research actually came out of the exploration system in the Constellation Program.

Mr. MOLLOHAN. Well, those are some of the benefits coming out of the Constellation Program.

General BOLDEN. Yes, sir.

LOST CONSTELLATION PROGRAM BENEFITS

Mr. MOLLOHAN. But there are those who are saying that those benefits aside, not going forward with Constellation is a waste because perhaps you are throwing away those benefits, but you are throwing away a lot of other investments, a lot of other progress, or is there a waste in going forward or are both correct?

General BOLDEN. Sir, as I mentioned before, I would not call it a waste, but I would say going forward with the Constellation Program as it exists today, going forward with the program of record puts us on an unsustainable trajectory considering the economics of today.

We would probably not get to the moon with a human until after the 2030s. I am convinced that with the technologies that we can develop, we will get there much sooner. We could not go to Mars probably not in my lifetime to be quite honest. I am convinced that given the opportunity to expend some funds on research and development, technology development, we can actually do that.

Mr. MOLLOHAN. Well, I am one that totally subscribes to the idea that President Bush announced a great vision and then did not fund it. But we are where we are. So why would we not just stretch it out, keep the investment, stretch out the investment, and not throw away the accomplishments up to date?

General BOLDEN. Mr. Chairman, I think one of the reasons that Constellation has grown the way it has is because that was the technique used. We stretched out the investments. You made the comment about the cost of the Space Station Program, that it was envisioned to be, $8 billion when proposed by the NASA Administration under President Bush or President Reagan and it ended up costing $40 billion plus.

What was not said in your statement was that the International Space Station, if I am not mistaken, is the third or fourth iteration of a space station and that resulted from stretching the program out and rewicking it looking for a better way to do it. I just could not in good conscience advise the President that we should follow that same course with the Constellation Program. Constellation today, the program of record today is a lunar-centric program. It has us trying to get Ares I that would take us to the International Space Station, take us to low-earth orbit, and then Ares V would come somewhere along the road. That would be the vehicle that we would use to go beyond low-earth orbit. The Ares V would get us to the Moon and it would get us there without a way to get down to the surface of the Moon. Altair, the landing vehicle, had not been funded. We were about to do some studies on it, but we had whittled away at the Constellation Program and had gotten ourselves in a situation that was essentially unrecoverable.

ARES I

Mr. MOLLOHAN. Well, elaborate on that. Why wouldn't Ares I, why shouldn't it become the basis for the U.S. astronaut transport to the space station?

General BOLDEN. Well, sir, in my opinion, Ares I is a very costly program that keeps us in the same paradigm that we have been since the earliest days of human spaceflight here in the United States with a huge infrastructure. That is in terms of facilities, people to run those facilities. We think that we can actually get away from that way of operating by utilizing the commercial entities that already build the vehicles for us and already operate the vehicles for us as they do in Shuttle today.

My vehicles today are commercial vehicles. Every Shuttle is a commercial vehicle built by a commercial vendor that will probably participate in the building of the commercial next generation vehicle. The only difference is the acquisition strategy used to operate that vehicle.

And today we buy shuttles. Well, we bought at the cost of about $2 billion a copy. In tomorrow's paradigm, I am not going to buy a vehicle, but I am going to use the vehicle produced by an American corporation in terms of, what do you call it, my idea is that we lease it and then we use it to fly a NASA crew to the International Space Station to do a mission.

The operation of that vehicle is primarily done just as it is today by USA with the Space Shuttle. It will be done by the vendor that owns the vehicle. The mission control center will be done just as it is today probably with Shuttle and the International Space Station. The people in the mission control center will be partially those from the company that built the vehicle and partially from NASA engineers and flight controllers.

Again, in my way of thinking, the operational concept, which has not been developed yet, but I will have a large part to play in what it ends up being, in my operational concept, the Flight Director is still a NASA person, the one NASA person that you can count on being in the control center.

Mr. MOLLOHAN. So you are not suggesting that Ares costs any less or any more than developing the technology and doing it commercially? You are suggesting, I think I am hearing you suggest that the savings is in the operations; is that correct?

General BOLDEN. I am suggesting that the production——

Mr. MOLLOHAN. Do we have a comparable development cost——

General BOLDEN. I do not——

Mr. MOLLOHAN [continuing]. Going commercial versus Ares?

General BOLDEN. Mr. Chairman, I actually think the development costs, which we pay in part through the amount that we pay for seats, I think the development costs will actually be somewhat less than Ares I. That is something that it is too early to say, but I do believe that.

Mr. MOLLOHAN. Well, what is the basis of that belief?

General BOLDEN. The basis of the belief is that the technology today, you know, it——

Mr. MOLLOHAN. You are pretty far down the road with Ares.

General BOLDEN. With Ares?

Mr. MOLLOHAN. Yes.

General BOLDEN. Sir, we have quite a way to go. You know, we just finished the——

COMMERCIAL ORIENTED APPROACH

Mr. MOLLOHAN. Well, does not commercial approach have as far to go or even further?

General BOLDEN. They have as far to go in one respect, but they are getting ready to actually test fly the vehicle here next year. In fact, we are going to test fly two of those vehicles.

Another potential source of commercial is the Atlas V and the Delta IV and those vehicles have been flying for quite some time. So for cargo to orbit, they are ready right now. If the companies that own them, if ULA decides that they want to enter the competition——

Mr. MOLLOHAN. The cargo——

General BOLDEN [continuing]. That will be another round.

Mr. MOLLOHAN. Yes. But cargo transport is not the defining goal here. It is——

General BOLDEN. Sir, the defining——

Mr. MOLLOHAN [continuing]. Human transportation.

General BOLDEN. The defining goal is commercial transport of crew to orbit. And we are at the same stage of development whether it is Atlas, Delta, Falcon, Taurus in terms of certifying them for spaceflight, for human rating. There is an involved process of human rating that we would have to go through with any vehicle.

Mr. MOLLOHAN. We are going to have to recess.

General BOLDEN. Yes, sir. I understand.

Mr. MOLLOHAN. We will return afterwards sometime. Thank you.

[Recess.]

Mr. MOLLOHAN. The hearing will resume.

I am going to have a couple continuing questions with regard to costs and timing of these two different approaches.

I believe your testimony up to this point was that you think the cost of a new commercial oriented approach would be less than pursuing the Constellation Ares approach; is that correct?

General BOLDEN. Mr. Chairman, I do. I went back and thought about it after you went out. When I last asked my folks how much it would cost us if we were to try to fly Ares, for example, Ares I, it turns out that it is about four billion to four and a half billion a year just for Ares I.

The primary reason for that is there are $600 to $700 million dollars alone just in the infrastructure that is left over right now from the Shuttle era. We need to phase out all of that if we are going to gain the cost savings that I anticipate we can do.

Mr. MOLLOHAN. What about if you used a different upper stage and a limited capability crew module, one not capable of transit to the moon? Would that be an acceptable approach and would that bring the cost comparison in line or would that give Ares a cost advantage?

General BOLDEN. Sir, are you asking if—let me make sure I——

Mr. MOLLOHAN. If you used a different upper stage, would the cost of Ares be significantly reduced through the use of a different upper stage and a capability of just going to the moon?

General BOLDEN. Mr. Chairman, the Ares I is——

Mr. MOLLOHAN. I am sorry. Station.

General BOLDEN. Oh, to go to station, the problem there we found was that in order to design and build a crew vehicle, it ends up being what some people call an Orion light. I am certain you get visited by the commercial entities every day and some of them will tell you that they would like to use a readily available expendable launch vehicle, an EELV with an Orion light.

Orion light is a vehicle that carries crew, but we would not send it anywhere outside of lower-earth orbit. So, you know, we end up having to design and build different vehicles for low-earth orbit than you do for the lunar and Mars missions. And it all——

Mr. MOLLOHAN. How is the commercial approach and the technologies and capabilities that are going to be developed there different?

General BOLDEN. Because the commercial vendors will develop their own—for example, if I name Space X, for example, their capsule is Dragon and it has the ability to cargo and crew with—you look at orbital, theirs is Cygnus. If you talk to ULA, either of their partners, Boeing or Lockheed Martin, they would probably use something like an Orion light. So the vehicle in which you carry the crew is going to vary by who the vendor is.

One of the things I would like to do is help them use some of the research and development money that we have to help build a common crew module that can be interchangeably used on a number of launch vehicles. We cannot do that today. Today everything is tailored. Everything is individual.

One of the reasons that it costs so much or when we talk about the 21st century range, that concept, it is because everything is unique today. I cannot put an Orion vehicle on an Atlas or a Delta or a Space X vehicle, and I would like to help the commercial entities design a single crew module because it is good for us to train in.

We do not have to train crews for multiple crew modules. That can be used interchangeably on any launch vehicle. We can not do that today or we have not done that today. But those are the kinds of things that you would be allowed to do with the President's budget when we talk about research and development.

HUMAN LAUNCH CAPABILITY TIMING

Mr. MOLLOHAN. Moving from cost to timing, what is the fastest path to restoring U.S.'s human launch capability, Ares, commercial?

General BOLDEN. It is my belief right now, Mr. Chairman, that the fastest path is the one that I helped the President propose and that is to go to the commercial entities to allow them just to qualify their vehicles first for cargo to low-earth orbit, to the International Space Station.

Mr. MOLLOHAN. All right. You are describing in your testimony a kind of faster, better, cheaper.

General BOLDEN. No, no. I——

Mr. MOLLOHAN. Not in——

General BOLDEN. You will never, Mr. Chairman——

Mr. MOLLOHAN. Not in the way that has been understood.

General BOLDEN. You will never hear me say faster, better, cheaper.

Mr. MOLLOHAN. Well, it sounds like it is going to be faster. It is going to be a better way of doing it and it is going to cost less when they say it like that.

General BOLDEN. Well——

Mr. MOLLOHAN. That is what you are describing.

General BOLDEN [continuing]. If it works out that way, that would be——

Mr. MOLLOHAN. Well——

General BOLDEN [continuing]. that would be incredible. But——

Mr. MOLLOHAN. And that is my question. What is your feeling testifying here today about it working out that way?

COST OF ASTRONAUT FLIGHTS TO LOW EARTH ORBIT

General BOLDEN. My feeling is that it will be cheaper for NASA to get to low Earth orbit on a commercial vehicle. Also, I do believe that we will get to the International Space Station quicker than we could with Ares I just because of where I found the program when I came in.

In terms of getting to the Moon, which is really NASA's ultimate goal, it is getting to the Moon and Mars, we cannot do that right now if we continue to march with the Constellation Program. That is my concern.

I really want to get NASA back into the exploration business and free us up from the day-to-day responsibility for operations of activities in low Earth orbit. That is critical and we will have oversight of that. But there is a big difference between oversight and day-to-day operations. And I want to get us——

Mr. MOLLOHAN. And that is where you see the savings, the cost savings——

General BOLDEN. I see the cost savings——

Mr. MOLLOHAN [continuing]. Managing these systems, the——

General BOLDEN [continuing]. In managing the systems and getting away from having to maintain the infrastructure, the things that we have to do today.

OBJECTIONS TO THE BUDGET REQUEST

Mr. MOLLOHAN. The Financial Times, the March 18th issue, there is a, and I know you read this, feature story, the Pull of Gravity. You are smiling already. And some of those who are expressing concerns about this program. I have a couple quotes here I would like you to respond to.

The President's proposal, opponents of the President's proposal from, and now I am quoting, from both political parties say the decision to turn from Constellation to the approach reflected in your budget jeopardizes national security, prestige, and commercial interests at a time when other countries are boosting their own space programs.

What is your response to that?

General BOLDEN. Sir, I disagree with that. I do not think it jeopardizes our national security. In fact, in my conversations with the national security representative if it is all the way from Secretary Donnelly, the Secretary of the Air Force, to General Kehler, to General Carlson, we all agree that going the commercial route is the best thing for the country. I think if you talk to any of us, we will tell you that. Is it risky? Yes, it is. But it is risky to go to space.

U.S. LEADERSHIP

Mr. MOLLOHAN. Further in the article, I would like you to respond to this, the article makes the point that NASA would pursue new technologies that could eventually take astronauts beyond earth orbit to places that humans have never visited such as asteroids or the moons of Mars, your argument, but there is no clear headline destination and no timetable for going further than the hundred billion dollar space station which has been assembled over the past 15 years as a collaborative venture group among the U.S. and its partners.

Is that the problem here, that you are not really articulating a vision that inspires or you are rolling it out piecemeal or why is this not grabbing a lot of people?

General BOLDEN. Mr. Chairman, my attempt to articulate a vision was to answer the question that everybody said. If you are not going anywhere, you are not going anywhere. We are going to Mars eventually. That is the destination.

As I have told everybody, I wish I could tell you the date certain, but I do not have the capability of getting there just yet. That is what I need time to put into place, the capabilities that will allow us to get there.

It is very important for people to understand we are still going to be, Americans are still going to be very active aboard the International Space Station for another ten years, thanks to the budget that has been proposed by President Obama.

In the article, it talked about national security and leadership. It is really important for people to understand that the International Space Station today is what allows us to lay claim, uncontested claim to international leadership in the world in human spaceflight.

I Chair something that is called the International Space Station Heads of Agency. It is an organization of five people who represent the five partners in the International Space Station, Russia, Japan, Canada, the European Space Agency, which is 15 nations that Mr. Dordan has responsibility for, and the United States. The Chairperson of the Heads of Agency is the United States. It is not questioned by anyone.

In our last meeting a little bit more than a week ago in Tokyo where we all endorsed extension of the utilization of the International Space Station, the statement was made by the Russian counterpart that the leadership of the United States is greatly appreciated and they hope that that would remain the case.

It is because we are the acknowledged leader. Everybody realizes that the International Space Station would not even exist today had it not been for us. Everybody wants to partner with us. That is something that our international partners make very clear every time I talk to them.

So it is very important that we not shrink from that, but that we also, as the President himself says, we have to take bold steps. We are a bold nation. Sometimes people confuse bigness with boldness. I am sorry. Sometimes you lead not by being out front where you are very visible, but you lead by being influential and being able to get people to do the things that you need to do. We do that every single day on the International Space Station.

When there is an issue, whether it is in a Russian module or a Japanese module or the European module, everybody comes to us. We pull the teams together in Houston whether it is by internet, by telecon or by video telecon or whatever, and the solution is made right in Houston.

So I cannot give a better example of leadership than that. I wish I could vocalize it better. We are the acknowledged leader in the world in human spaceflight. Unless we choose to say we are, that is not going to change.

GENERAL BOLDEN'S EXPERIENCE

Mr. MOLLOHAN. General, how long were you in the Astronaut Corps?

General BOLDEN. Sir, I was there for 14 years right in the middle of my 34 years in the Marine Corps.

Mr. MOLLOHAN. How many Shuttle flights did you participate in?

General BOLDEN. I flew four and my first flight ended ten days before we lost Challenger. And my next three came in the wake or in the aftermath of Challenger when I realized that it was so important that we do what we do that I remain a part of the program.

CONSTELLATION PROGRAM CONTRACTS

Mr. MOLLOHAN. That would suggest you had some insights into these issues.

A final question here. In our report last year, we included this provision "provided, none of the funds provided herein and from prior years, shall be available for the termination or elimination of any program, project, or activity of the architecture for the Constellation Program, nor shall such funds be available to create or initiate a new program, project, or activity unless such program termination, elimination, creation, or initiation is provided in subsequent appropriation Acts."

There is some concern that or some question about whether that provision is being strictly complied to. Can you speak to that question?

General BOLDEN. Mr. Chairman, that provision is being strictly complied to. We have not terminated nor cancelled any contracts in the Constellation Program. We have not directed the slowdown of anything in the Constellation Program. I have authorized the cessation of procurement activities, five different activities that were in the process of going through competition to become contracts and I have explained that to members of Congress before. They were decisions that I felt were prudent because they had to do with downstream Constellation type projects.

One of them was construction of the processing platforms at the Kennedy Space Center. We would not have gotten to that in 2010 anyway. So, I just stopped the procurement activity that would have gotten that contract.

Another one was for what we call an Eagle contract. It is the ground support. It is all the engineering and everything at the Kennedy Space Center. I on the recommendation of Bob Cabana, the Center Director at the Kennedy Space Center, terminated the efforts on that because his advice to me was, if we compete this contract and it is won and we do not have a budget that funds a follow-on program, I am going to have people out of work because they will be working under a contract that is not funded.

And there are three others that I could mention that we stopped because it——

Mr. MOLLOHAN. Well, with regard to that one, could anybody fairly consider that to be a termination?

General BOLDEN. No, sir. That was not a termination because we did not have a contract. So all of the existing Constellation contracts their work is still being fulfilled.

I did ask people please do not expand the scope of any work, please do not go out and begin any new work because I am not authorized to do that.

Mr. MOLLOHAN. In regard to the decisions that you have referenced here in answer to my previous question or with regard to any decisions you might have made that could be construed as being covered by my question, have you consulted lawyers in making those decisions?

General BOLDEN. Sir, I consult my Office of General Counsel before every decision and frequently we consult lawyers from other organizations which I have learned is not always, and I do not say this meaning any slight about attorneys, but——

Mr. MOLLOHAN. Of course.

General BOLDEN [continuing]. As a general rule when I ask for multiple opinions from multiple organizations' attorneys, then I get multiple answers. So I do count on my General Counsel who I consider to be an incredible attorney and his team. So the advice was that I was not in violation of the 2010 Joint Appropriations Act and I do not believe I have done any of that.

Mr. MOLLOHAN. So based on your——

General BOLDEN. In fact, the GAO is about to undertake or has already initiated an investigation into just those things. It will allow me to have an outside organization assess that I have not violated the law, that I did not violate the direction of the Congress.

Mr. MOLLOHAN. So with regard to these questions and those decisions, you feel, your testimony is here today that you have made all of them in compliance with the law based upon the advice of your lawyers?

General BOLDEN. Yes, sir, I have.

Mr. MOLLOHAN. Mr. Wolf.

PRESIDENT'S PROPOSAL FOR SPACE EXPLORATION

Mr. WOLF. Thank you, Mr. Chairman.

And I apologize for not being here at the outset. I was Chairing a hearing on Human Rights and Religious Freedom in Vietnam, so hopefully the questions will not repeat.

But I talked to a lot of people about this. There are two things. One, everyone thinks you are a fine person. So I think if there were a vote on that, you would win a hundred percent.

The other side of the coin is that not many people that I have spoken to, some who have interest because of jobs, but others who just care about the country, do not agree with the Administration.

Some of the comments. Former NASA Administrator, Mike Griffin, said I believe this budget request advocates a strategy that is frankly disastrous for U.S. human spaceflight.

Dr. Chris Kraft, the legendary Apollo Flight Director and former Johnson Space Center Director said, "the U.S. Space Program is in great peril if the President's budget proposals are enacted."

Apollo 7 astronaut, Walter Cunningham, said "the proposal accelerates, quote, accelerates America's downward spiral toward a mediocrity in space exploration."

Apollo 17 astronaut and former U.S. Senator, Harrison Schmidt, wrote this proposal, "would cede the moon to China, the American Space Station to Russia, and assign liberty to the ages. Other nations would accrue the benefits, psychological, political, economic, and scientific, that the United States has harvested as a consequence of Apollo's success 40 years ago. This lesson has not been lost on our ideological and economic competitors."

Apollo 16 astronaut, Charlie Duke, said we cannot afford to lose our leadership in space.

Then it goes on. I will not go through them all? I will just ask unanimous consent to submit them for the record.

[CLERK'S NOTE.—Letters can be found following QFR responses.]

I have a series of question. The first is, the President's proposal for space exploration has not been embraced by many members of Congress. There are some that have. But overall, it has not.

I made an effort to solicit the views, positive or negative, of space exploration experts, former astronauts, and former Administrators. And I have done it in a very intellectually honest basis. I would call them and say just tell me, and I could off the record sit down with you and tell you who, what do you actually think. Some were astronauts, but some were not. Some were in the program. Almost no one has an involvement with regard to jobs.

And one of the most frequently heard criticisms is that there is no set mission goal. And what are the goals of the new program and what time table will these goals be achieved?

General BOLDEN. Sir, the primary goal for NASA with the President's new program is to be able to put humans on Mars in the foreseeable future. As I have explained before, the difficulty in doing that and the reason that I cannot give you a time certain is because we lack certain technological capabilities to do that. That is what is the basis for the technological development programs that I would like to put in place, so that we can develop those technologies and the capabilities that will allow us to do that.

The reference you made to the group, and I did look at the document and I appreciate your giving me that before, they are very learned people, but I contend that the paradigm that they use is the paradigm of the Cold War when we had a defined enemy. So it was a matter of defeating the Soviet Union in the Cold War.

We did not do anything in partnerships at that time. It was the United States against if we need to. That is not the paradigm under which I have grown up, in my 34 years in the Marine Corps. Today we do international partnerships and we will not be able to go to Mars, we will not be able to go back to the Moon unless we are able to team with our international partners.

The International Space Station which right now is the focus of any hope to be able to go beyond lowearth orbit. That is an international effort. So, I think they remember the way it was when we had a defined enemy and you could state that, okay, we are going to beat that enemy to a certain finish line, if you will.

People talk about losing out on the race to the Moon to China. That is impossible. We already won the race. There is no race to the Moon. We won it. Whenever any other nation gets to the Moon, they will find six flags and all six flags will bear the colors of this nation. They will have a different number of stars depending on when they were there, but, they will be United States flags.

As I tell people all the time, they will probably, because the moon surface does not get disturbed like ours, they will probably walk in some footsteps. Those footsteps will be the footsteps of the 12 American astronauts who first set foot on the Moon. So there is no race. We have won that race.

Mr. WOLF. A lot of the——

General BOLDEN. There is no backup leadership. We are the designated leader.

Mr. WOLF. A lot of the individuals I am referencing, and I will send you the letters, too, are not in that category. They are younger people, younger than you, some of the best minds in the country, a vast array of people. And they say basically the same thing. And I am going to share everything I have with you so that there is no surprises.

WORKFORCE CONCERNS

The Shuttle Program is being closed down at the end of this year. NASA was already faced with the difficult task of transitioning the Shuttle workforce into the Constellation Program. Now you are proposing to terminate the Constellation Program at the same time.

What do you anticipate are the impacts of this decision on the workforce, both Civil Service and contractors? How many jobs will be lost and what measures do you plan to take to minimize the impact of job losses and the negative impact on the industrial base?

General BOLDEN. Sir, as I think everybody knows, the Obama Administration is not the Administration that brought about the closeout of the Shuttle Program. We have been working on that since 2004.

While I was sad to see it come, it was time. We have learned a lot of lessons in going through the Shuttle transition process. So, we think we know how to transition as we close down a program.

So, while we were going to be able to transition a portion of the Shuttle workforce to the Constellation Program and this has exacerbated that somewhat, we think we know how to transition a workforce to a new program. And as I mentioned earlier, it is my hope that we will be able to announce the programs that we would have as follow-on under the President's proposed budget.

CENTER JOB LOSSES

Mr. WOLF. Well, how many jobs do you foresee being lost?

General BOLDEN. Sir, I will get that information for you for the record because I do not want to—you know, we know that in the Kennedy Space Center area from the Shuttle Program, it was probably going to be in the neighborhood of 5,000, but then we were going to get some that we would transition to Constellation. But I will get the definitive numbers for you for the record for each of the centers affected.

WORKFORCE TRANSITION

NASA is assessing the workforce implications of the FY 2011 budget request. While more precise workforce projections are not likely to be available before the submission of the FY 2012 budget request, the Agency believes it will be able to support delivery of the next Workforce Transition Strategy update—with updated, by-Center estimates for the Space Shuttle and Constellation programs and parametric estimates for new work, reflecting the President's proposed budget—by this August. In May, the Agency plans to deliver an update on its workforce transition efforts that will focus on employee assistance and related activities. While the May document will not include workforce projections, it will reflect the significant ongoing transition activity that has occurred since the July 2009 edition of the Workforce Transition Strategy as NASA has continued to work towards the retirement of the Space Shuttle, and will set the stage for the August edition of that report.

LEADERSHIP IN HUMAN SPACEFLIGHT

Mr. WOLF. Okay. Many have characterized this proposal of ceding leadership in manned spaceflight to other nations. Charles Krauthammer wrote that decades from now, there may be a robust private space industry, but "in the interim, space will be owned by Russia and then China."

What are the implications of this, because we also have seen that the Chinese are very aggressive? And you say that we have won and we have, but the opportunities for ceding that leadership, because once you are ahead in the race and fall behind and somebody comes up, what are the implications if China gets back to the moon—gets to the moon before we return? Do you see any implications?

General BOLDEN. Sir, I do see implications to it, but they are not necessarily bad. You know, if the Chinese choose to go to the moon while we are trying to go to Mars and we are able to develop the technology necessary to do that and we reach both destinations simultaneously, which we could, you know, it depends on how long it takes them to get there, then I would say once again——

CHINA AND THE MOON

Mr. WOLF. But you were mentioning going back, you said, to the moon and then to Mars. Assuming you are going back to the moon and China is going to the moon, who gets there first the next time?

General BOLDEN. Oh, the next time?

Mr. WOLF. Yes.

General BOLDEN. Sir, I do not intend, it will sound trivial, but I do not think it matters who gets there.

Mr. WOLF. Well, it does to me. It does to me. And I think it matters, with all respect to a lot of Americans. I mean, it may not with you. And, believe me, I admire your service, so I want to make that clear. But it does to me. And I think it does to a lot of young people. We are trying to increase math and science and physics and chemistry and get excitement. And people do not sign up to get the autographs of the Land Rover. They line up to get the autographs of the astronauts. So I think it does.

Somebody said the other day astronauts are the only people that people stand in line not knowing who they are just to get the names, the autographs of people they do not even know. They do not do that with other people. So it matters to me and I think it matters to a lot of others.

But based on that question, who do you think gets there first the next time? Do we get back to the moon before China or does China get to the moon before we get back to the moon?

General BOLDEN. Sir, because of where we are technologically in comparison to them, I think we get back first. If I am allowed to carry out the vision of President Obama and as supported by the 2011 budget, I think we stand a pretty good chance of getting to the Moon much quicker than we would have with the Constellation Program.

PRESIDENT'S PROPOSAL

Mr. WOLF. The President's proposal seemed to take NASA workforce by surprise. To what extent was this new plan developed and vetted and refined by the NASA scientists, engineers, and managers who represent the country's best qualified experts in space exploration?

General BOLDEN. Congressman, for months prior to the budget being announced, I had worked with my senior staff. But development as a general rule happens at the—is an iterative process. When we prepared our inputs, then there were participation among all my senior staff in providing the input for the budget.

Mr. WOLF. Well, that is not completely what we hear when we talk to someone.

General BOLDEN. Congressman Wolf, if I may——

Mr. WOLF. Yes, sir

General BOLDEN [continuing]. The data that we put together for submission for a budget does not mean that, it is like any budget. Everybody puts in what they want and then you go negotiate and you get out maybe not everything that you asked for.

Mr. WOLF. Well, I understand. For five years, I worked for a Cabinet Secretary, former Congressman Roger C.B. Morton. And when big decisions were made in a particular area, if it dealt with national parks, the National Park Director would come in, the park superintendents would come in. It was an in-depth kind of consultation before the Secretary just rolled something out.

And the centers most impacted by this decision, Kennedy, Johnson, and Marshall. So I guess directly were the Directors of those centers part of the team making the decisions on the new proposals and, if not, why not?

General BOLDEN. Sir, all Center Directors as well as all of my Mission Directorate Associate Administrators were involved in all the deliberations that we made prior to my going in and meeting with the President and working on the budget with him.

But as I said again, everything that you propose does not always come out the other end. I think the budget that we got is the best budget for the nation and the best budget for NASA. It essentially represents what I recommended to the President.

REVIEW OF THE NEW PROPOSAL

Mr. WOLF. Okay. I just will have one other on this round, Mr. Chairman. I appreciate that.

After talking to a number of these people, and I appreciate the conversation I have had with you, in light of the widespread opposition, and I think you would acknowledge there has been some fairly widespread opposition, on March 11, I and several other members wrote to you asking you to assemble a team of NASA experts to conduct a 30-day review of the new proposal tested for ground truth and suggest possible alternatives and modifications within the current proposed budget. Will you be conducting this review?

General BOLDEN. Congressman Wolf, we are constantly reviewing everything that we do. And I think you will find when I respond to your letter, that we have looked long and hard at ways to—for example, the one question you asked about, ensuring continuous American access to low-earth orbit, we continue to look at that in hopes that we would be able to find a way to do that. We are unable to do that. So that will be a response that I will give to you. I am working on your response.

Mr. WOLF. So are you looking then? Or have you looked and decided not to? The request was to take 30 days because the President is going to go down to Cape Canaveral on April 15th. When something is rolled out then, then you are going to have kind of a fairly significant complication.

Is there an effort to develop, and I do not know if the word is compromise, but is there an effort to look at this thing again and compromise?

General BOLDEN. Congressman, my intention is to continue to work with the Congress. I know that the President is going to work with the Congress.

But I think in your letter, if I remember, you asked if I were looking to develop a plan B and there is no alternative plan. There is no alternative budget. I stick by the budget that I helped the

President develop. So if the question is am I developing a plan B, there is no plan B.

Mr. WOLF. And what if it is rejected by the Congress?

General BOLDEN. Sir, it is my intent to work diligently to find a solution to the differences that we have on the different parts of the budget. I think, and I hope I am not being presumptive, but I think with the exception of the portion of the budget that deals with the cancellation of the Constellation Program, we are probably in unanimous agreement that we have an incredible budget. So my intent is to focus on work with the Congress and I know that that is the President's intent.

Mr. WOLF. Well, I guess I could take that as a, yes, we are going to try to accommodate and work or I could take it as it is and I am uncertain.

It troubles me, as you know, I do not support what you are doing, some parts are positive, but I am already getting calls and hearing that some of the companies and our lobbyists downtown, former members of Congress, people who really are working on this not necessarily for America but to make a profit. And that is, I guess, the way this process works in this town.

But are you open to other ideas or is it just the way it came out?

General BOLDEN. Congressman, personally I am open to any ideas that come through my organization. I constantly challenge my Center Directors and all of my employees to help us determine better ways that we can do what we do.

We have a budget that has been proposed by the President. As I said before, I think it is an incredible budget. I think it gives us great opportunities. And I think within the constraints of the budget, we are going to find a way to get America to mars in due course and we are going to develop the technologies utilizing the funds that hopefully will be appropriated in that budget to get us there quicker than we would have been able to do under the program of record, under the present Constellation Program.

So that is my focus. And I really want to work with this body to make sure that we are able to do that.

Mr. WOLF. Okay. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Mr. Ruppersberger.

U.S. SPACE PROGRAM

Mr. RUPPERSBERGER. Yes, first I know that your position as Administrator, you have the President's budget and, you know, there are issues there. Once he puts out the budget you are going to have to defend that budget. I want to say I respect your role as Administrator. And one of the reasons is because you were an astronaut and you understand the business, and that is important.

My concern is that if you look at the history of our country, and how we evolved to be number one in space, it all started really I think with Sputnik. And when the Russians came out with Sputnik we were concerned they were going to control the skies. And we got together as a country, our American ingenuity, our education, and we put a man on the moon in twelve years.

Since that time, though, we have had a lot of failures in the space program. We have lost billions of dollars and we have had to cancel other programs. And the issue of canceling a program is very serious when you have had a lot in it but you cannot keep throwing bad money, and you have to have, if you are a leader you have to make certain decisions and prioritize.

My concern is the way this was done, because I think it has happened way too quick. When you read about it in the paper, and those of us who deal in space and deal with, whether it is military intelligence or NASA. And I am concerned that we do not have the road map. That we all of a sudden have a plan, and because of the fact that we have 25,000 jobs at stake, we are competing with Russia and China, I think it could put us at a disadvantage.

So I want to ask you a couple of questions. The first thing, you have said that you feel that clearly we are number one in space at this point. But I think you also, do you feel that there are a lot of challenges that we have ahead of us?

General BOLDEN. Sir, I think there are definite challenges that we have ahead of us and they would be there if we had no competition.

HEAVY-LIFT CAPABILITY

Mr. RUPPERSBERGER. All right. One of the challenges that I am concerned about is launch. It is my understanding that we have not, are not where we need to be with respect to launch, that probably Russia and China are ahead of us as far as launch capability. And I think this is something we really have to focus on. And I hope that you have certain priorities that you are focusing on the launch issue. There is a lot, whether it is resources, whether it is management, but it is something I think that we have to deal with it. We have had too many cancellations that seem to we are going down the wrong road on launch. Do you have an opinion on that?

General BOLDEN. Congressman, you and I have talked about this in the past, as I have with several other members. This is an area of concern for all of us who are involved in the national security arena or space access arena. Just as recently as last week I was involved in a video teleconference with the space related agencies in our government, led by Secretary Donley, the Secretary of the Air Force, and General Kehler, General Carlson and me. The issues that we discussed included the need for a broad national launch system that will put us back where we need to be. We are too reliant right now on old systems, and that is one of the reasons that I try to reemphasize the importance of President Obama's budget. Because in that he has challenged me to find state-of-the-art propulsion systems, both for leaving the planet but most importantly for in space propulsion. So that we can get to the places like Mars, and asteroids, and the Moon, much quicker than we can do today.

NASA'S BUDGET

Mr. RUPPERSBERGER. All right, I understand that. I want to get back to the President's budget again. I think that when you have such a large program, so many jobs at stake, our national security at stake, you really have to focus on where your priorities are. But you have to work with the group. And what I mean by the group, the DOD. You have to work with intelligence. You have, with NASA where you are. You also have to work with Congress. And I feel that there needs to be more of a balance that has not occurred yet. I think by moving so quickly, and having to be here to defend, I think that we ought to really take a couple of steps back and evaluate where our priorities are going to be as far as jobs, as far as money.

And I agree with you on the commercial issue. We have not, because we had more money than anybody, that is one of the reasons why we are superior in space. Europe is doing very well with commercial. They are getting a lot of the same pictures that we are getting. They are getting a lot of same information that we are getting. So we have to make sure, if we can have four satellites to one, that we really explore commercial. But commercial will not get us to the Moon, commercial will not get us to Mars. And this is why I am concerned that based on the President's budget at this point, that if we, if we are taking man, we are really not focusing on space involving the ability to get a man to the Moon or to Mars, it is almost as if we are having a mile race to China and we are giving them a half-mile head start.

We know the money that China is putting into their space program. And I think if we are going to collaborate, and we are going to work with these other countries, that we have to be stronger so we have the leverage to work with them. And I would like your opinion on if you feel there is a way of flexibility to work with us, to make sure that we can reevaluate and we can help you put together a plan so that we have all of the entities, American entities, whether it is military, intel, that is coming together. Because I think right now you are going to spend a lot of time defending a budget when maybe we should spend more time on how we can be successful in the future in our space program.

General BOLDEN. Congressman, I appreciate that and that is exactly what I intend to do. I want to go forward, and I do not want to stop, retrench, go back and look at something. Mistakes that I have made, I have made, I cannot correct that. If I were to go through the budget roll out again I would not do it the way I did it. I would listen to some of these people sitting behind me who advised me that this is the way we usually do it. I thought I was smarter, and I have apologized for that before.

HEAVY LIFT PROPULSION R&D

Mr. RUPPERSBERGER. Let me give you an example of what I would mean, though, why we have to reevaluate. Heavy lifting propulsion R and D. Fiscal year 2011 budget for heavy lifting propulsion R and D, it looks like you are spending $5 billion over the next five years. Now, your budget proposes $3 billion over the next five years for a heavy lift vehicle. This is not adequate funding for a heavy lift vehicle development program and will require a top line increase in NASA's budget. Now, in those five years are we going to build, test, or fly anything? And with these funds it looks like we are only going to study. We have, we have done a lot of study and research, and we need to do the testing and the research. But there comes a time when we have to make a move. Now, I am going to ask the question. In those five years are we going to build, test, or fly anything?

General BOLDEN. Sir, it is my hope that we will build, test, and fly things in this coming period.

Mr. RUPPERSBERGER. What will that be, then? That we are going to test?

General BOLDEN. Well sir, the reason——

Mr. RUPPERSBERGER. Based on this budget? I do not see that.

General BOLDEN. Well the reason that I have asked that we be allowed to take an opportunity to look at what is available in current technology and where we think we can go is so that we build smartly. We design and we develop smartly. I think there are better capabilities than we presently have today, and I want to make sure that when we build and test a rocket that it is the best we can do.

Mr. RUPPERSBERGER. No question.

General BOLDEN. I think we can get there within the constraints of the present budget, and then, we will certainly be required when we get ready to really start going to Mars——

Mr. RUPPERSBERGER. Getting back to my question, though, if Constellation is canceled, and I hope we can look and reevaluate that. Maybe there are a lot of things that need to be canceled within that program, but the whole program being canceled I believe is too quick. But let me ask this. And I do not know where my time is, Mr. Chairman. But with Constellation being canceled, should we not be looking to make sure we are pressing forward with good heavy lift capabilities? I do not see it with a $3 billion over five years. I do not think we can get there with that.

General BOLDEN. Sir, I have asked my, one of the things that we are doing with the teams that I know everybody is not happy with, but one of those teams is a heavy lift launch vehicle team. They are assessing what will be required for us to, as speedily as possible, develop a new heavy lift launch vehicle that will get us where we want to go. So I think when we finish that work we will be ready to proceed to develop what the nation can be proud of.

CYBERSECURITY

Mr. RUPPERSBERGER. My time is up? Oh, I have got to get into cyber, too. Because that is another area that we have to deal with. And we know, and it is not classified, that we have had, that NASA has had a lot of cyber attacks, especially from China, throughout the years. And, you know, a lot of what we do in space deals with a lot of issues, some that we cannot talk about. But, you know, how we, commercially, our national security, and whatever. Where is NASA now as far as the focus on cybersecurity? Are you working with NSA, since NSA has jurisdiction over the .mil. What is your plan for cybersecurity?

General BOLDEN. Sir, I brought in a new Chief Information Officer shortly after taking over as the NASA Administrator. And she knows that that is probably her number one focus. We have actually begun to work with other agencies and other organizations that have had perhaps not as many hits as we have had but more severe intrusions. We are trying to learn lessons from them so that we can restructure ourselves.

One of the things we could not do, or did not choose to do before I became the Administrator, was devote the funds necessary to strengthen our cybersecurity——

Mr. RUPPERSBERGER. Are you working with NSA to protect these networks?

General BOLDEN. Sir, I will get back to you for the record.

CYBER SECURITY

The NASA Chief Information Officer is working closely with members of the intelligence community and Department of Human Services on matters related to cyber security.

Mr. RUPPERSBERGER. Okay, well then you do not have to——

General BOLDEN [continuing]. Do not want to say specifically the agency that we are working with. Not that I do not want to, I do not want to tell you that we are working specifically with NSA if I do not, and I do not know that we are working specifically with which organizations. But I will get that information to you.

CONSTELLATION PROGRAM

Mr. RUPPERSBERGER. Okay, the final question is about Constellation being canceled. You talked about going to Mars maybe in twenty years, and maybe that, we are not sure where our priorities are. It seems to me that is a long way off, and that we need to maybe refocus our priorities and our goals. But I think at this point if we just, one year Constellation is there, the next year maybe a loss of 25,000 jobs, that if we do not reevaluate where and what we can take out of Constellation, if it is going to be canceled, where we are going to put these jobs, where we are going to get the best. You know, China and Russia are Communist countries. They can order the smartest people in that area to work wherever they make them work. We cannot. So I really would hope that you would reevaluate that twenty years, because I cannot see a goal twenty years out with canceling Constellation. I think we have to work up to that.

So I am just saying we are going to work with you. You are going to get a lot of accusations, and there is emotion just like the healthcare emotion and, you know, everything else. But this is so serious to our country and our national security. And I think you are the right person in the right place, by the way.

General BOLDEN. Congressman, if I may? I share your concern about having a target that is twenty years away, and trying to tell the American public that, "Just wait twenty years." That does not get it, and I say that. What I have told my leadership team, and everyone in the NASA workforce, all 18,000-plus of them, is that if we cannot do something that gets people's attention preferably every year, but every other year, then we are going to be lost. I really believe that.

And what the President's budget allows me to do is to launch smaller test flights of technology. I do not have to have a specific vehicle to launch a technology test. I can use anything. I can put something on one of these commercial vehicles that is going to the International Space Station. I can fly it on a commercial vehicle that is doing their own thing, taking tourists around the planet. I can fly it on a suborbital vehicle. I can, that is the way we do things today. We put more than one payload on a satellite. Or we put a payload on somebody else's launch vehicle that has nothing to do with what we are trying to do. That is what the money for technology development is going to allow me to do. Because we cannot, we cannot just fly, twenty years from now. We have got to be doing things that are causing us, or allowing us, to get incrementally to where we want to go. And that is exactly what I want to do.

Mr. MOLLOHAN. Mr. Visclosky.

HEAVY-LIFT LAUNCH VEHICLE CAPACITY

Mr. VISCLOSKY. Thank you, Mr. Chairman. Mr. Administrator, thank you very much for your time. And in many ways you have answered the question I am going to ask you and that is about lift capacity. I serve on a Defense Subcommittee as well and we are very concerned as far as launch capabilities. You had mentioned your meetings with the Air Force, and you had talked about crew modules, and cargo. As you are looking ahead, is it your anticipation that you are going to use something along the lines of the evolved expendable launch vehicle? Or will there be a new system in place as far as launch capabilities?

General BOLDEN. Sir, if I understand your question correctly, for a heavy lift launch vehicle my intention would be that that would be a newly developed system. We can use the EELVs for any number of things. We can use them for getting to low Earth orbit. We can use them for getting satellites to orbit. But that would not be my vision, that we would use that as the nation's heavy lift launch vehicle to try to get us to Mars. And that is simply because in the——

Mr. VISCLOSKY. I am not talking, I am sorry, I am not talking about Mars. I am talking about just this country's base launch abilities. And are you as you pursue new launch capabilities for NASA, you mentioned Air Force——

General BOLDEN. Yes, sir——

Mr. VISCLOSKY [continuing]. Are you working——

General BOLDEN. My desire is to——

Mr. VISCLOSKY. Put out of your mind human space flight.

General BOLDEN. Yes, sir. I understand.

Mr. VISCLOSKY. Okay.

General BOLDEN. There are needs for a heavy lift launch vehicle for national security purposes. So, my intention is to develop in coordination and consultation with the other space agencies that need that capability, so that we build a nationally usable heavy lift launch vehicle. The same thing with propulsion systems. I want to be able to develop the first stage engines that can not only lift a NASA crew and cargo that is going to go to Mars, but will be able to lift something for the national security apparatus. Or even the commercial entities can use it on a vehicle should some business entrepreneur decide that he or she wants to fly something to the Moon.

Mr. VISCLOSKY. And you are hopeful you would see that flight within five years? If I understood your answer to the gentleman from Maryland?

General BOLDEN. Sir, I do not think I said we would have a heavy lift launch vehicle in five years, no sir.

Mr. VISCLOSKY. Okay. Do you have an estimated time?

General BOLDEN. My desire would be to get us on a trajectory where we can realize a heavy lift capability by, within the next ten years or so. That is what we show on most of our forecasts if we are able to expend the funds the way——

Mr. VISCLOSKY. And you are in consultation with DOD?

General BOLDEN. I am in consultation with DOD and the intelligence communities also.

Mr. VISCLOSKY. And you believe you have enough money in the 2011 budget to pursue that?

General BOLDEN. I have enough money in the 2011 budget to begin the pursuit, yes sir.

ROBOTIC SPACE EXPLORATION

Mr. VISCLOSKY. A more philosophical question if I could. And this is the first time I have had a NASA hearing. I believe the agency does an incredible amount of good work with unmanned exploration of space. Do you have a list at NASA of projects and proposals for unmanned exploration that we simply do not have money on because of the cost of keeping a human being alive in space, that are being unmet?

General BOLDEN. Yes, sir. I could give you——

Mr. VISCLOSKY. I would take, I guess, an approach different from colleagues——

General BOLDEN. I could give you a long list of those that existed while we were trying to sustain the Constellation program. As I have said before this panel, before this Committee and others, Constellation itself was on an unsustainable trajectory to getting where we wanted to go in human space flight. While doing so it was sucking all the oxygen out of the room in terms of support to aeronautics research, science research, and the like. That is no fault of the people involved. That is just a fall out of the funding that went to the program over the last ten years. I just do not know how to explain it any better.

But in the 2011 budget I think you will see, I would love for us to be able to talk about the ninety-some odd percent of the 2011 budget that is really, really good. And it is the increase in spending on Earth science, climate science, planetary science, pulling missions forward that we, that came out of the decadal surveys by as much as a year to two years. When we start flying these missions in, I think, 2013, 2014, there is going to be a string of missions that we could not honestly say we would be able to pull off——

HUMAN EXPLORATION AND ROBOTICS

NASA is continuously engaged in the study of potential future missions and projects. The Agency is guided in this process by national needs and priorities as well as by scientific priorities as established by the National Academies of Sciences. The sets of meritorious and exciting robotic missions identified by the National Academies inevitably exceeds the available resources. NASA considers a balanced program that includes both human exploration and robotic exploration to be essential to America's future in space exploration. Robotic and human exploration are mutually supportive and interdependent. NASA's FY 2011 budget request reflects an appropriate balance between these two critical activities.

FY 2011 PROPOSALS

Mr. VISCLOSKY. And let me ask you one final question, setting aside human space flight and setting aside Earth science, what are some of the things you would, under the proposed 2011 bill, be able to do that you would not have been able to do?

General BOLDEN. Under the 2011 bill in the field of aeronautics we are going to do, I think there was recently the FAA authorization bill passed that put a significant plus up in the FAA budget for Next Generation Air Transportation Systems. We are vital cogs in the wheel in producing that system. I would like to be able to get to the 2011 budget because it has a significant amount of money that we are going to be able to put into the NASA portion of the development of next year. When you look at green aviation, or when you look at other types of things in the field of aeronautics, that is all covered in the 2011 budget where the aeronautics budget had pretty much shrunk to about half of what it used to be over the last eight or ten years.

Those are the things that I am very excited about——

PLANETARY SCIENCE

Mr. VISCLOSKY. Any additional programs in planetary science?

General BOLDEN. I beg your pardon, sir?

Mr. VISCLOSKY. Any additional programs in astrophysics or planetary science?

General BOLDEN. We have some that we are now hopeful that we can fly that were doubtful before. The one that I like, because it goes to a place called Europa, where we think that it is an ice-covered moon of Jupiter that we think has a huge ocean beneath it. Where there is an ocean there is a possibility of some type of life. So for a planetary scientist, or a life scientist, that is exciting.

Mr. VISCLOSKY. Thank you very much. Thank you, Mr. Chairman.

NASA'S ROLE

Mr. MOLLOHAN. Mr. Culberson.

Mr. CULBERSON. Thank you, Mr. Chairman. General, thank you for your service to the country and your leadership at NASA. We all admire you immensely and just continue to hear great good things about you. I especially appreciated, Mr. Chairman, I think your line of questioning was right on target, Mr. Wolf's. And particularly I want to follow up on Mr. Ruppersberger's and Mr. Visclosky's line of questioning. I think the questions they asked are right on target.

The concern we all have as part of our job as members of this Committee, as members of Congress, is to protect the nation's national security interests and NASA's role in preserving America's national security is vital. That ability to have a heavy lift vehicle, the manned space program, there is just no substitute for it.

HUBBLE REPAIR

Hubble could not have been repaired, the initial problem with the mirrors, the final, the other two repairs. I think you actually flew on one of the, did you fly on one of the repair missions?

General BOLDEN. I put the flawed telescope into orbit.

Mr. CULBERSON. You were on the first one, then, that fixed the spherical aberration problem with the mirrors?

General BOLDEN. I, when I left it we did not know it. But a couple of weeks later when we started to check out we discovered we had what was called a spherical aberration. And that is all I am going to say, because somebody told me that but I cannot describe it.

Mr. CULBERSON. That is right, you were on that. And I do not think a robot could have done that, could they?

General BOLDEN. I also worked on the National Academy of Science Committee to save Hubble. And we thought we could support NASA's intent to develop a robotic mission to Hubble. When I talk about the necessity of technology development, at that time in 2003, 2004, when I met, although it was our firm intent to find a robotic method to go and service Hubble the technology was not there at the time.

Mr. CULBERSON. Right, it had to be a manned mission.

General BOLDEN. It had to be a manned mission. And——

Mr. CULBERSON. And so many other ways.

General BOLDEN [continuing]. We were able to convince the incoming NASA Administrator Mike Griffin that it was worth the risk.

THE HIGH GROUND

Mr. CULBERSON. Right. The problems you encounter in space, whether it be the deployment of a solar panel, or whatever has happened before, you have just got to have human beings in space. And that is an absolutely essential part of America's national security. And space is the high ground today, is it not? That is the high ground.

General BOLDEN. It is the absolute high ground. Going back to your point, robots can do almost everything. But today they do not reason, they cannot. Although they are very good, we build dexterous robots. I think you and Congressman Wolf hopefully saw R2 in a recent visit to the Johnson Space Center?

Mr. CULBERSON. Yes, sir.

General BOLDEN. R2 can do amazing things, but R2 cannot think.

EUROPA MISSION

Mr. CULBERSON. Right. Well your, and I was glad to hear the Europa mission. Mr. Visclosky is right, how important that is that NASA also maintain world leadership in exploring the outer planets. And those are now of necessity robotic missions. The Europa mission in particular, the highest priority of the decadal survey, because Europa has more liquid salt water than the Earth even. And we know it has got heat, there is almost certainly volcanic vents and life. Very exciting mission, look forward to seeing that blossom and develop and fly.

HEAVY LIFT LAUNCH AND HUMAN CAPSULE VEHICLE

But Mr. Ruppersberger asked and Mr. Visclosky a very, very important question, and I cannot see it either, they are all as concerned as I am, about the heavy lift capability of NASA that we just do not see it in the budget. And I would say to Mr. Visclosky and Mr. Ruppersberger, the letter that Mr. Wolf sent you in asking how within the existing budget can we preserve the ability to have a manned capsule and heavy lift vehicle within the existing budget? That question we asked I think would give us the fall back, if you do not want to use the word compromise, position that we are all looking for. So you will be able to answer that question within the thirty days?

General BOLDEN. Congressman, it is my intent to get your response, a response to Congressman Wolf in the very near future.

Mr. CULBERSON. So within the timeframe Mr. Wolf gave you?

General BOLDEN. In that timeframe Mr. Wolf——

CONSTELLATION PROGRAM CANCELLATION

Mr. CULBERSON. Super. That is critical. Because, Mr. Visclosky, Mr. Ruppersberger, I know members of the Committee, members of Congress, and I, we have only been able to find one member of the House that supports the President's budget proposal. And we need to make sure we will as a nation preserve America's leadership in manned space exploration. And the key is to find a reasonable middle ground, and that letter will help us do that. How many——

General BOLDEN. Congressman, may I make one, please?

Mr. CULBERSON. Yes, sir.

General BOLDEN. Because the tone of your comment, I want to make sure that everyone understands, I am not developing a Plan B. There is no Plan B. There is no alternative budget. But I am trying to answer the Congressman's letter——

Mr. CULBERSON. Yes, sir. That is right. We will do that.

General BOLDEN [continuing]. Within the constraints——

Mr. CULBERSON. Yes, sir.

General BOLDEN [continuing]. Of the President's proposed budget.

Mr. CULBERSON. Yes, sir. The President——

General BOLDEN. As long as everybody understands that.

Mr. CULBERSON. The President has made a proposal and we will, yes sir. I wanted to ask you, General Bolden, the President's budget was announced on February 1st. How many days before that did you first hear that the Constellation program was going to be canceled?

General BOLDEN. Sir, that particular piece is what they call predecisional. I am not, I think it would be inappropriate for me to talk about the date on which the President, I was notified——

Mr. CULBERSON. Well what I am really driving at, though, is that the, the decision to cancel Constellation was a surprise?

General BOLDEN. Sir, because of the way that I chose to roll out the NASA budget, and I did not go through the normal process of getting with members of this Committee, or other members of Congress several days before the budget was announced, then it was a surprise to the world.

Mr. CULBERSON. It was a surprise to you?

General BOLDEN. Oh, no sir.

Mr. CULBERSON. And a surprise to, certainly a surprise to the center directors. And Mr. Wolf is right. We, Mr. Wolf has talked with all of them. I have talked extensively with Mike Coats, who I just admire. He is a national treasure, take good care of that man.

General BOLDEN. Yes, sir.

Mr. CULBERSON. It was a surprise to everybody. Because the Augustine Commission said that the Constellation program was unsustainable because of inadequate funding. And the reason we are in the box ring today is because of inadequate funding from the Bush administration Office of Management and Budget and failure to fully fund the vision that was laid out prior to the election in 2004. So that is the dilemma. It is not that there are any inherent flaws in the Constellation program. The Constellation program is, was on track, had a successful test flight? Right? It was on track? It was inadequately funded.

General BOLDEN. Congressman——

Mr. CULBERSON. That is the problem with Constellation.

General BOLDEN. I wish I, I honestly wish I could say that it was a singular problem of funding. Funding was the principal driver in causing the Constellation program to be unsustainable. But the Constellation program as it is had been downgraded to the extent that it, as I mentioned earlier, it had denigrated to, or degraded to a lunar program. And it was a lunar program without a lander.

Mr. CULBERSON. Right.

General BOLDEN. Those decisions, while they had to be made because of insufficient funding, they put us in a situation where we almost could not recover.

COMMERCIAL ASTRONAUT LAUNCH

Mr. CULBERSON. Thank you. Thank you. And if I could, Mr. Chairman, I will be as brief as I can because I understand they have called a couple of votes, you said earlier, General Bolden, in your testimony at the beginning that essentially what you envision, and I tried to write this down accurately. What you are envisioning is that NASA will, you will no longer buy vehicles, NASA will lease them. And the operation will be by the vendor who owns the vehicle, correct?

General BOLDEN. Yes, sir.

Mr. CULBERSON. Okay.

General BOLDEN. And "lease" is my term.

Mr. CULBERSON. I understand.

General BOLDEN. The acquisition strategy has not been decided yet.

Mr. CULBERSON. Yeah, yeah——

General BOLDEN. But that is the closest thing I can, lease it as opposed to getting it as a taxi. I differentiate it between the taxi service and getting the vehicle that becomes mind for a period of time.

Mr. CULBERSON. Right. The analogy, the concern that I think we all have as members of Congress is, can you imagine the United States government having to lease the USS Harry Truman from Northrup Grumman? If Northrup, imagine if Northrup Grumman owned the Harry Truman, and we had to lease it, or ask permission to take it to the Persian Gulf. That is really what you are talking about.

General BOLDEN. Sir, I do not, I appreciate the analogy.

Mr. CULBERSON. Or the nuclear subs. You know, General Dynamics. Imagine if we had Mr. Visclosky go to the General Dynamics and lease a USS Texas, for example. That is really near and dear to my heart. There is a big problem there.

SPEECH BY DEPUTY ADMINISTRATOR GARVER

And then finally Mr. Chairman, let me point this out because I know time is short, but the, and I do not know if the Committee is familiar with this, and I am going share this with you. Lori Garver gave a speech on March 10th to the American Astronautical Society. And I, this was dumbfounding to me. The statute creating NASA, Congress' direction to NASA, and the nation's direction, is that NASA's job is, "to pioneer the future in space exploration, scientific discovery, and aeronautics research." Lori Garver told the American Astronautical Society that NASA's priority are to fight poverty, promote world peace and societal advancement, and protect the environment. I, this is, I think, she says and I will quote it directly. She says, "The President's budget will enable NASA to align with the priorities of the nation, and these key national priorities that I am referring to are economic development, poverty, hunger and jobs, international leadership and geopolitics, world peace, education, society advancement, environment, future of the planet, and humanity." And I would suggest to you that Ms. Garver has completely lost sight of the core mission of NASA, which is to preserve and protect America's leadership in manned space, manned and robotic space exploration to pioneer the future in space exploration, scientific discovery, and aeronautics research. To go where no one has gone before and explore new world. And that is NASA's mission. It is, NASA's mission is not fighting poverty, world peace, and protecting the environment. Those may be subsets or spinoffs. But I, you know, Ms. Garver's, I will make sure my colleagues see this. This is very disturbing. Were you aware of this?

General BOLDEN. Congressman, I——

Mr. CULBERSON. Is your vision of NASA that NASA's number one job is to fight poverty and world peace? Surely not.

General BOLDEN. Congressman I, know Lori incredibly well and I know that Lori knows what the mission of NASA is.

Mr. CULBERSON. Well, this is what she told the astronomers at——

General BOLDEN. I do not think she questions whatsoever what our charge is and what our mission is under the National Space Act and the subsequent appropriations acts.

Mr. CULBERSON. Would you please talk to her and get, I mean, this needs to be retracted. This is not acceptable.

General BOLDEN. Yes, sir.

Mr. CULBERSON. You do not agree with this, do you?

General BOLDEN. NASA's mission as established by the National Space Act has not changed. NASA's mission, is still what it is.

Mr. CULBERSON. So you disagree with Ms. Garver? You disagree with this speech?

General BOLDEN. Congressman, that is the first I have seen that.

Mr. CULBERSON. I will share it with you, make sure you see it. Thank you. Thank you very much, Mr. Chairman.

Mr. MOLLOHAN. Was Ms. Garver asserting that that was the sole mission of NASA? Was she asserting that was the sole mission of NASA?

Mr. CULBERSON. Yes, sir. The speech was to the——

Mr. MOLLOHAN. No, I'm not asking you, was she asserting that was the sole mission of NASA?

Mr. CULBERSON. Yes, sir. Yeah, these are their national, these are NASA's, aligning with the priorities of the nation, and here are the priorities.

Mr. MOLLOHAN. I did not hear that was the mission of NASA. My question is, was she asserting that was the sole mission of NASA?

Mr. CULBERSON. She lists all the other things they are doing as spinoffs. Yes, sir. This is their lead role. This is their lead mission.

Mr. MOLLOHAN. So you are saying she said in that speech that those are the sole missions of NASA?

Mr. CULBERSON. The sole mission? This is NASA's mission. Yes, sir, this is NASA's mission.

Mr. MOLLOHAN. You——

Mr. CULBERSON. The word mission is not, but it is clear that is what she is saying. I mean, it——

Mr. MOLLOHAN. Ah, thank you. Mr. Honda.

Mr. HONDA. Thank you very much. Just to gentlelady Garver, I guess there are a lot of visions that we have of projects that we get involved in. And it is probably her vision that ultimately all the things that we do scientifically and socially, it is for ultimately world peace, and getting along with each other, and creating international cooperation. Not unlike the Spaceship Enterprise, hm?

General BOLDEN. Congressman, I think if we are allowed to take her speech in context I think it would be the same thing that I do. Anybody that has heard me speak knows that the most passionate part about anything I say is about education.

Mr. HONDA. Yeah.

General BOLDEN. That is not NASA's primary mission. And I am criticized by some of my predecessors and some of my contemporaries because I focus, I put big focus on education because I think it is critical for this nation. I think that NASA has a responsibility to partner with the President in trying to pull our nation out of its, now if you want to talk about leadership, we are twenty-something in the world in math and science. We have got to be the leader there. And I think while that is nowhere in NASA's mission statement from the National Space Act, I do not think, it is incredibly critical that we play a role in that. I just think we need to look at Lori's comments in context.

Mr. MOLLOHAN. Excuse me just one minute, would the gentleman suspend for a minute? We have six minutes to finish this vote, which means we have some more minutes. I plan to go past the voting time. And we have three members, including Mr. Honda who is now questioning, and then any second rounds. If we cannot finish before, which is perfectly fine, I intend, if the Administrator is able, to return after the vote for further questions. I just wanted to let the members know that.

NASA'S MISSIONS

Mr. HONDA. Thank you, Mr. Chairman. And thank you for the continued comments regarding science. Because I, you know, one of the things that would, we could think about reestablishing is a independent office, like the old Office of Biological and Physical Research. But I think in the last few years that I have been here we have been trying to keep the A and the S in NASA, you know aeronautics and space. So I think after the shuttle disaster things got a little bit disarrayed and confused. And then I think that the way NASA was being administered in terms of its mission, its budget, and everything else like that, it seemed like we sort of tried to find out why. I think that it caused a lot of confusion. We lost a lot of good scientists and good contractors on that way.

It feels like the administration, it feels like the administration is trying to refocus and capture what we have, what we inherited. And it seems like the piece that the Constellation, that is left over from the Constellation is that piece of the heavy lift portion. And I heard you say that you did not cancel any contracts, you just said, "Let us stop and figure out where we are going to go from here." And it feels like that, that might be part of the piece that the Augustine Commission was looking at when they said that you all ought to look at some of the different options we put out there. And some of them are, I guess it was suggesting a flexible plan so that you have options and in using some of the different options you might be able to catch up and recapture the lead in the space exploration.

You stated very clearly that the vision was not necessarily staying at the Moon but going to Mars. And in order to do that we have to probably bring back the issues around human biology in space and the other things that were cut out. And a lot of things were cut out, I think, to support the old Constellation program. And I think we lost a lot of pieces in there. And I think, it feels like you are trying to look at how do we piece it back together so that we have a coherent program so that we can move forward? Would you like to comment on that?

General BOLDEN. I would be happy to comment on that. NASA can walk and chew gum, and we can keep many balls in the air. As you said, the National Aeronautics and Space Administration, the aeronautics have suffered. Through no fault of any of my predecessors, but we just did not have the funding to support a robust aeronautics program. President Obama in the 2011 budget proposal is giving us significant amounts of money to rebuild our aeronautics program, to put money into colleges and universities so that we can get researchers who will want to do research in aeronautics and basic science in any number of things.

We talk about inspiring kids, and Congressman Wolf have talked about this a lot because he does it with a school in this area. Kids have got to have someone to whom they look up. While I agree they will stand in line to get the autograph of an astronaut they have never heard of, but they make decisions about what areas of study they are going to go into based on the professors and what they are doing when they get to college. Today in colleges and universities across the country we are not putting sufficient money in for research and development. President Obama's proposal for 2011 will allow me to put money back onto college and university campuses. I think professors are going to be doing robust research and development that is going to help us do the things that we have talked about, help us get a better heavy lift launch vehicle, and kids are going to want to be with them.

Some of them, hopefully some few, will want to be astronauts. But most of them are going to decide that they want to go to graduate school, and that they want to become a professor. That is just not happening today in the fields of science and engineering. Most of our students are turning to business. Not that it is bad, but we need scientists and engineers if we are going to continue to lead the world in technology.

RETAINING CONTRACTOR EXPERTISE

Mr. HONDA. Just very quickly, given what you said, and I think that is the right direction, and the uncertainty that we are faced with right now, what is it that we are going to be able to do to hold the contractors and the experts that we have currently and not lost them because of the uncertainty? What is it that we can provide them so that they hang in there until things become more clear?

General BOLDEN. Congressman, I have a two-headed workforce. I have civil servants and then contractors. And it is the second head of my workforce, it is the contractors that I am concerned about. Because in going away, in phasing out the shuttle program, we were going to lose some of those jobs. We were trying to find ways to help them transition either into another program in NASA or to the civilian workforce in the fields of science and technology. We have another challenge now in that we have decided that it is best to cancel the Constellation program and move on to something that will enable us to do the things we want to do much sooner. So it is incumbent upon me to work with the contractors and help them find ways that we can transition as many members of the workforce as possible to our follow on programs. But we will not be able to place everyone. So it is incumbent upon me to work with them to find transition programs where we can try to get them into other jobs in the high technology community. Because that is the way the nation has to go, if we are going to remain the leader. I pledge to all of them, I meet with the CEOs and the leaders of these companies on a regular basis, and I have asked them and told them, I want to be a partner with them in finding ways that we can find employment for their people. That is not going to be easy. But I am not the only aspect of American society that is going through that right now.

Mr. HONDA. Thank you, Mr. Chairman.

Mr. MOLLOHAN. General, we are going to recess. Are you able to stay past 4:00?

General BOLDEN. Sir, I am able to stay until you are ready to go home. This is my day today.

Mr. MOLLOHAN. There are several other members that have questions. Mr. Wolf may have some more.

General BOLDEN. Sir, I can stay as long as you all can stay.

Mr. MOLLOHAN. Thank you.

General BOLDEN. I can stay longer. I am a Marine.

Mr. MOLLOHAN. Well, we will see.

General BOLDEN. Thank you, sir.

[Recess]

HEAVY-LIFT TECHNOLOGY

Mr. MOLLOHAN. The hearing will resume. I am going to ask a few questions before we get some other members back. General, you had some questions with regard to heavy lift. Let me ask, what are the challenges in heavy lift technology, and to what extent are the technology requirements dependent upon the ultimate mission?

General BOLDEN. Sir, the principal challenge in any launch vehicle is mass. My exploration systems associate administrator has shown me a chart that he has that shows you historically as we have progressed in space exploration we have been able to get the mass of the vehicles down. So that is one of them. That may be just in the material that we use to construct the rocket. We now have something called "friction stir weld." It is a means by which we put components together that makes them much stronger, but it is much less weight than in the old method where you applied molten metal to a joint. Friction stir weld just takes two pieces of material together and it uses pressure and heat, and it bonds the material from its own composition instead of adding something to it. So they tend to be much lighter weight. We use it quite a bit now in the external tank and in some of the other, and it was actually developed for the dome of one of the Constellation modules, but that is just a technique that came about from Constellation.

So propulsion is the big challenge. And I was having a discussion over here, whereas I am not, to be quite honest I am not real confident that we are going to find any revolutionary type of propulsion to leave the planet. You can take much less weight with you if you are able to develop propulsion systems that can be refueled on orbit, or if you go to Mars, you can dramatically reduce the amount of weight you have to take to the planet if you have a way to get in situ material, material that is there, like methane. So, if you develop a LOX-methane engine that can be refueled on the Martian surface because you have developed a method to take methane from the planet, then you reduce the amount of weight required for a heavy-lift launch vehicle.

Mr. MOLLOHAN. Which speaks to the last half of my questions. The rocket is the substantial part depending upon the mission, and the design of it?

General BOLDEN. Yes, sir.

Mr. MOLLOHAN. Mr. Schiff.

CONSTELLATION PROGRAM CANCELLATION COSTS

Mr. SCHIFF. Thank you, Mr. Chairman. Thank you for being here, Mr. Administrator. You have a very tough job. And in many respects I think the job your predecessors had was easier because we had the vision, we did not have the resources, but we were content to suspend belief. But we have to come to grips with the financial realities.

There are three things I would like to ask you about. One is, I know one of your colleagues testified, the President's Science Advisor, that he was not sure what the cost would be of canceling Constellation. That it was a very substantial sum, the attorneys were still trying to figure that out. Are the contracts written in such a way that the taxpayers can get, if there is a major change of direction like this, taxpayers can get their money's worth in the sense that the contractors can be redirected to do the R and D, or other work, that will be useful in building the program and the launch capability, even if it is not building Constellation? Doing the R and D? Do we have the flexibility to do that so that we are not just paying liquidated damages?

General BOLDEN. Congressman, that is one of the things that I have asked each of the tiger teams or the teams that are looking into the Constellation program. One of the things that we do want to determine is, are there contracts either in existence or contracts that we were considering that can be transitioned to a new program so that you do not go through termination liability, you do not go through a lot of the other things that, where you incur cost because you are completely doing away with a program. We are not there yet. I wish I could tell you today that we have answers in all these regards. But that is one of the things that we are looking at. How can we take advantage of what we have in Constellation that we may want to use as a part of another system? And just transition that over to the other system? There are methods to do it, but I would really mislead you if I tried to describe them because I am neither informed nor educated on them.

ARES V AND HEAVY-LIFT CAPABILITY

Mr. SCHIFF. Well I would think that it would have three benefits. The first is making good use of the taxpayer dollars, not just paying damages. The second is you maintain a lot of those jobs. And then the third is that you maintain the skilled workforce. So I would hope that we would maximize the degree to which we do not pay damages but rather put the contractors to work in a new direction, if that is the course we head in.

What kind of a budget would you have needed to have to go forward with let us say the Ares V, to go forward with the heavy lift capability? And let me give you the context of my question, which is it would be, I am sure, very advantageous to the Defense Department, to our intelligence agencies, to have access to our satellites. If we have a malfunction in a satellite, or we have aging components in a satellite, it would be of a great, you know, probably ascertainable value to DOD and intel to be able to say, "Okay, we have the proprietary capability to get to that satellite to make repairs." And we could probably project that into the distance, however long it would take us to develop that capability. So to the degree that, you know, we may not be able to redirect the workforce that is working on Constellation, and have to pay damages, if you take that sum and you invest it in a proprietary capability, let us say an Ares V kind of capability, if you take a DOD investment, or an intel investment, and what it would save them from seeing satellites that malfunctioned or aged out, and have the capability to be repaired, does that get you close to the budget that you would need to go forward with the proprietary capability? And how much time does that shave off of the current plan that you have developed for heavy lift?

General BOLDEN. Congressman, I asked about this because I thought it would be much less if we kind of picked and chose. Just to do Ares I would be in the neighborhood of $4 billion to $4.5 billion a year, on top of the President's budget proposal. Say we wanted to do that and do all the science and technology development, the aeronautics increase, and everything else. The Constellation program in 2011 had it, were it to go on, you are probably talking up to $5.9 billion over and above. I cannot really say that we would be able to get where we want to go any faster, even having spent that amount of, if we were to spend——

Mr. SCHIFF. How is that, though? I mean, if we decide that, you know, Ares V is the design we want to use, and we just start the development of Ares V, how can that possibly take longer than doing R & D on other potential lift technologies, settling on a new technology, developing that new technology, how could that possibly be quicker than developing Ares V?

General BOLDEN. Congressman, I think the biggest thing would just be the fact that we would not be able to—let me ask a question here because I want to make sure I understand your question. You are saying if we decided that we were going to put the money into Constellation to develop Ares V, and not add any, just take money the way we could find it? If that is the question you asked, without putting an additional $5.9 billion on top of the program, what we would find would be that we would have a heavy-lift launch vehicle with no capability of putting people on the surface of the Moon or on Mars or anywhere else because we would have expended all the money on the vehicle itself. We would find that we are back in this conundrum that the Augustine Committee found us, where money was really not the only problem. It was a significant problem. But it was not the only problem because we had allowed the program to deteriorate to the point that if you threw all this money down here, it was not that we had things waiting to be built.

For example, one of the procurements that I stopped was a study for the Altair, the lander. The Constellation had not been allowed to go that far because of the shortage of funds. So, we would have found ourselves having to go from scratch to do the studies on development, and design and development of a lander for them.

EUROPA MISSION

Mr. SCHIFF. Let me ask you about one other subject matter area. The budget does do a great job of funding Earth science missions, and continues funding for current planetary science missions. It does not, however, move future planetary science into the formulation stage. In particular, the outer planets flagship mission to Europa is not moved forward. The budget mentions NASA is awaiting the results of the upcoming planetary science decadal survey before finalizing the mission, or formulating the mission. But this mission was recommended in the last decadal. My understanding was that NASA had also endorsed Europa, and to be followed at some later time by Titan. So why are we kicking this can down the road again? I mean, how many decadals do we have to have recommend Europa? And if this was ready to begin development, why are we not moving forward? Why the delay?

General BOLDEN. Congressman, I will have to get back to you with the details. But as I think you had discussion with Ed Weiler, with my Science Mission Directorate Associate Administrator. I went back and talked with him after I consulted with you, and I think it is a matter of making it a priority of the agency when the decadal comes out, and list it where we think it is going to be listed in terms of priorities. I think you are familiar with the tier system that they use. I do not know why it did not rank high enough in a previous decadal, but I will go back and ask the question.

Mr. SCHIFF. Well I mean it has always, I mean, it did rank very highly in the last decadal. And Mr. Culberson is not present at the moment, another big advocate of Europa. But last year, and I think the year before, we went through kind of a similar permutation. And NASA finally kind of made a decision, let us do Europa, let us do Titan next. Now it seems we are stepping back from that. And if you could get back to me I would like to——

General BOLDEN. I will do that.

Mr. SCHIFF [continuing]. I would like to see this——

General BOLDEN. Yes, sir.

Mr. SCHIFF [continuing]. Us move forward with this, and not, you know, punt it again, and go through another kind of soul searching about it, that it enjoys such support in the scientific community.

General BOLDEN. Sir, I will get back to you. Because I got excited about it after having talked to you and Ed Weiler, and again, because I am just a Marine I did not realize that Europa had what it has. And that is pretty exciting, as I said to somebody.

EUROPA

As you noted, NASA takes its priorities for its science missions from the National Academy of Science's decadal surveys. These surveys involve the broad scientific community and peer review to delineate the highest priorities for future missions and research targets for the next decade. The Europa-Jupiter System Mission was identified by National Academy in the 2003 Planetary Science Decadal Survey as the highest priority flagship planetary mission. Because of this, NASA recently initiated discussions with the European Space Agency (ESA) to significantly increase the potential science return from this mission as a possible joint mission. NASA's budget over the past several years was fully subscribed by the Planetary Science missions in development, and did not afford the initiation of any flagship missions.

NASA FY 2011 budget request does not include funding for the Europa-Jupiter System (EJSM) mission, as NASA is awaiting results of the NRC Planetary Science Decadal Survey before setting a budget priority and pace for this future Outer Planets mission, vis-à-vis other Planetary Science programs. However, funding is included in the FY 2011 budget request to continue to invest in technologies to mitigate several key mission risks that a Europa mission would encounter, such as technologies for radiation-hardened science instruments and components necessary to survive the harsh radiation environment in which this mission will operate. NASA and ESA have cosponsored three instrument workshops, with a fourth and final workshop scheduled for July 2010 to help prepare the science community to design these radiation-hardened science instruments. NASA will fund the conceptual study and preliminary analysis for this mission and initiate a two-step instrument selection process, all of which would significantly reduce the cost risk for this future mission.

NASA's ability to move forward with any major Outer Planets mission is also dependent on the availability of Pu-238 needed to power this mission. Pu-238 has provided power for 26 different missions that NASA has flown over the years, most of which would not have been possible without the radioisotope power sources that require this particular fuel. Both the Department of Energy and NASA requested $15 million in their FY 2011 budget request to restart the nation's ability to produce this critical isotope.

ORBITING CARBON OBSERVATORY (OCO)

Mr. SCHIFF. Last item is OCO. I am glad the decision has been made to do OCO again. Do you know what the planned launch date is for OCO?

General BOLDEN. Sir, we are looking at 2012, I think. And I will get back, I will make sure that I enter it into the record, the official launch. But I, as my memory serves me, I was hoping we would be able to turn it around real quickly, but I think it is 2012.

MARS SCIENCE LABORATORY (MSL)

Mr. SCHIFF. And finally, any progress report on MSL, on the Mars program?

General BOLDEN. Sir, the reports on MSL are all good. You are very well aware of the fact that we were in the doldrums a couple of months ago because we had problems with titanium, which is almost everything on the vehicle. We had problems with actuators that we did not know whether they would even last. According to what I have been briefed, all of the actuators have now been cleared, the titanium has been cleared, and I think we are on target for a 2011 launch date for MSL. We even have, as you may or may not know, there is always a good side to every bad thing that happens to you. The delay has actually allowed famed director James Cameron, who is actually a scientist of a sort. He has a 3–D camera system that is going to allow us to bring down real time images of Mars unheard of before. The development of the camera just did not come along to make the original launch date, because of the delay they have been able to do it, and we can really swap out the camera now. So, instead of having two mono cameras we are going to have a real 3–D camera.

Mr. SCHIFF. I hope you get a cameo out of it. Thank you, Mr. Chairman.

General BOLDEN. And I just got something that says the projected launch date of OCO is February of 2013, so I was in error.

Mr. SCHIFF. Thank you.

Mr. MOLLOHAN. Mr. Aderholt.

COST ESTIMATE OF ARES I AND ARES V

Mr. ADERHOLT. Thank you, Mr. Administrator. Thank you for your service and as has already been said by several members on this Subcommittee you have a fine reputation and everyone agrees that you are certainly someone that people hold in very high regard. I know sometimes we may disagree with some of the things, so you know, do not take any of this personally. It is all, we just sometimes have different opinions on some of these issues.

AUGUSTINE COMMISSION COST ESTIMATES

There is a strong reason to question the dollar figures that were produced by the Augustine Commission. Can you provide the Committee the Ares I and the Ares V cost estimate NASA had last spring, they had estimated last spring? And also provide the Committee with a written, detailed explanation from NASA as to how operating Ares I would cost $4 billion a year?

General BOLDEN. Sir, I can provide that for the record. I will be glad to do that.

ARES I AND ARES V COST ESTIMATES

Ares I *operational* costs, if the systems were completed, would be an estimated $3.6–4B per year, which equates to the estimated annual operational costs for two crewed flights to the ISS following successful completion of the IOC, currently targeted for March 2015. However, this estimate assumes that NASA has received full funding to fully complete development of the Ares, Orion and associated support elements prior to IOC. (Note: NASA does not currently believe an IOC of 2015 would be achievable, given the impact of several FY 2010 appropriations actions, including the FY 2010 Continuing Resolution.)

NASA recognizes that there is often confusion with regard to publicized flight cost estimates associated with the Ares projects, largely because those estimates often include different assumptions. One key point of confusion, for example, comes from the fact that the Ares I and Ares V share significant fixed costs for vendor production base and sustaining engineering, since both vehicles would use similar solid rocket boosters, upper stage engines and avionics. Therefore, there are two ways to consider the cost of an Ares I flight—one, where the Ares I fixed costs are lower because it is assumed that certain fixed operational costs would be shared with the Ares V, and another, where the Ares I fixed costs are higher because the current shared-cost scenario is not assumed.

In general, NASA does not budget by flight, but rather by fixed and marginal costs expected on an annual basis. The fixed cost (i.e. prime and non-prime support labor, costs of facilities) would be the cost that must be incurred whether one rocket or multiple rockets are built. In other words, the fixed cost is absorbed by the first annual flight and is not counted again that year. The marginal costs, on the other hand, are those costs that can be cleanly attributed to the production of one unit, and that cost is generally the same, unit by unit. So for each subsequent annual flight, NASA adds on only the marginal cost, given that the fixed cost has already been absorbed into the first. It is important to note, however, that NASA's formula of calculating the cost of an Ares I flight (or subsequent annual flights) does not include the project costs for the associated support elements, such as ground operations, mission operations, EVA and program integration. Those costs would be book kept under their respective project lines.

With regard to the cost per flight, NASA currently estimates that both Ares I and Orion account for $69M each in marginal costs for a flight unit, thus totaling $138M in marginal costs for each flight since each flight would be assumed to have a capsule and a rocket. However, the fixed cost per flight would vary based on whether Ares I and Ares V shared operational costs were assumed.

For example, the FY 2010 budget request assumed that Ares I and Ares V would share some operational costs—approximately $700M per year, which would, in turn, equate to lower fixed costs for the Ares I. Therefore, under that scenario—which was provided to Congressman Aderholt's staff in November 2009—the total cost for the first flight would be $919M ($781M in fixed cost plus $138M in marginal costs) with each subsequent flight costing $138M extra in marginal costs, as outlined in the chart below:

ESTIMATED ANNUAL OPERATIONS FIXED AND MARGINAL COSTS FOR ARES I AND ORION WITH ARES I AND ARES V SHARING OPERATIONAL COSTS

[Dollars in millions]

	FY08
Fixed Costs (Ares I and Orion)	* 781
Marginal Cost for 1st flight	138

ESTIMATED ANNUAL OPERATIONS FIXED AND MARGINAL COSTS FOR ARES I AND ORION WITH ARES I AND ARES V SHARING OPERATIONAL COSTS—Continued

[Dollars in millions]

	FY08
Total cost for first flight	919
Marginal Cost for 2nd flight	138
Total cost for 2 flts per year	1,057
Marginal Cost for 3rd flight	138
Total cost for 3 flts per year	1,195

* Note: This assumes Ares I fixed costs are shared with Ares V. It also excludes fixed costs for supporting elements.

However, if the assumption is that Ares I and Ares V would *not* share operational costs, it is equally true to say that the cost of an Ares I flight is nearly $1.6B—. Under this scenario, all operational costs would be carried by Ares I—which would account for an approximate $700M increase in the fixed cost for Ares I. Thus, under this scenario, the total cost for the first flight would be $1.461B in fixed cost plus $138M in marginal costs, with each subsequent flight costing $138M extra in marginal costs, as outlined in the chart below:

ESTIMATED ANNUAL OPERATIONS FIXED AND MARGINAL COSTS FOR ARES I AND ORION WITH ARES I CARRYING ALL OF THE OPERATIONAL COSTS

[Dollars in millions]

	FY08
Fixed Costs (Ares I and Orion)	* 1,461
Marginal Cost for 1st flight	138
Total cost for first flight	1,599
Marginal Cost for 2nd flight	138
Total cost for 2 flts per year	1,737
Marginal Cost for 3rd flight	138
Total cost for 3 flts per year	1,875

* Note: This assumes Ares I fixed costs are shared with Ares V. It also excludes fixed costs for supporting elements.

NASA is unsure about the source of the number cited since there are similar figures often used, albeit with different assumptions included in each. However, judging by the hearing exchange, it seems the question derived from a discussion about how much it would cost to keep the Ares project running in FY 2011. If that is indeed the question, then, in order to understand the cost of the Ares I project, it is important to understand the full cost of the Constellation Program. Based on the FY 2010 budget request, NASA estimates it would cost $5.4B in FY 2011 to continue the full Constellation Program, including Ares I and Orion development and testing, and all supporting elements (ground processing facilities, mission control, program integration etc.) which together would lead to an Initial Operational Capability for two crewed flights to the International Space Station per year. Of the $5.4B figure, the Ares I project was estimated to cost $2.1B, with Orion costing $1.8B, and other Constellation supporting elements equating to about $1.5B.

The FY 2011 budget request transitions away from the Constellation Program. Therefore, under this assumption, if NASA were required to continue only the Ares I project, the cost to do so would be about $4–4.5B in FY 2011—which would pay for the project elements and also include the full cost of *all* supporting elements outlined in the FY 2010 budget request, such as ground processing facilities, mission control, program integration etc. Without these supporting elements, the Ares I could not fly. This scenario also assumes that Orion would be cancelled, so close-out costs for Orion were factored into this estimate. (Note: Without an Orion, this scenario would not provide an IOC capability.) Additionally, it is important to remember that under the FY 2010 budget request and its five-year runout, the Constellation Program as a whole was expected to begin ramping up work in FY 2011, and in doing so, was expected to also begin assuming additional Shuttle infrastructure and workforce costs in addition to increased development costs, currently estimated to be $600–700M. Therefore, those costs are factored into the continuation cost estimate.

Mr. ADERHOLT. And the reason I mention that was because the, you know, my staff was given the numbers of Ares I, the operation cost at $1.3 billion.

General BOLDEN. That is per flight.

Mr. ADERHOLT. Okay. So you are saying——

General BOLDEN. I do know that, I do know that the $1.3 billion, $1.6 billion, and when I talk about things that shocked me, because, I wanted to use an Ares type vehicle as a test vehicle. And when I asked the question how much would it cost me to fly, not an Ares I but that kind of vehicle, then the number given me at the time was $1.6 billion per flight. It seems like an extreme number to me, and I am still looking. So I will be glad to provide you with the information for the basis for that number.

Mr. ADERHOLT. Well the reason I say that is because this is the response from NASA and it says total cost for three flights in a year is $1.1 billion.

General BOLDEN. I will go back and double check my numbers, and then get back to you for the record, sir.

ANTIDEFICIENCY ACT

Mr. ADERHOLT. If you could, yeah, give us some explanation on that. Because there is some difference, a big difference in the amount of money that is in there. It is, it has been rumored that NASA is about the send the prime contractors of the Constellation program letters which remind them of the Antideficiency Act, and telling them that NASA is under no obligation to cover termination costs beyond appropriated funds. I just wanted to, is that correct? Or——

General BOLDEN. Congressman, I think most of the contractors are fully aware of what is in their contract. They realize that they are obligated by their contract to reserve funds that would be needed for termination liability. One of the things that I have asked be done is that we go out and get estimates from the contractors as to what their estimate on termination liability will be. And then that will determine what type of action that we take. I do not think we have seen more than a couple of the contractors that have said they have a significant problem. And in that case, it may be necessary for us to have the contracting officers talk with them about their obligation under the contract as opposed to ours.

Mr. ADERHOLT. So you are saying there is no, no letter is about to go out like that?

General BOLDEN. There probably are letters going out to some of the contractors who say that they thought it was our responsibility. There probably are.

Mr. ADERHOLT. Was this the direction of OMB?

General BOLDEN. No, sir, that was my direction, because under the Antideficiency Act, I hope I am wrong, but I am legally liable if I allow a company to spend more than I have to pay them, I go to jail. So, I am very serious about wanting to be around for my three granddaughters. So on advice of counsel, it was felt that we should at least remind people of what is in their contract. And you would think that that would not be necessary. But in some cases, it may be necessary.

Mr. ADERHOLT. Certainly I can appreciate the going to jail aspect of that. So what do you think the contractors will do in response?

General BOLDEN. Sir, I don't even want to conjecture on that. But, I hope that they will take it as, responsible direction.

Mr. ADERHOLT. Is there similar letters that are going out to contractors about the shuttle program?

General BOLDEN. To my knowledge, we have no letters that are going to any of the shuttle contractors, because as I mentioned before, we have a very well developed transition plan for shuttle that covers termination costs and everything. That is pretty well known.

So I will get back to you if I find that I am incorrect. But I think shuttle is in pretty good shape in terms of termination.

TERMINATION LIABILITY

Termination liability letters are not being sent to Space Shuttle Program contractors. The Shuttle contracts are not being terminated—they are being concluded as the fleet flies out the remaining manifest. Plans for the safe fly-out and retirement of the Space Shuttle have been underway for several years, and were initially developed in 2004. Space Shuttle contractors have, therefore, had sufficient time to plan for contract closeout activities.

Mr. ADERHOLT. Okay. If you could get back on it, it would be great.

General BOLDEN. And it is not—I don't even know if it is termination. I will get back to you, because I don't think it is termination in the case of shuttle. That was an orderly phase out from 2004 to 2010 agreed upon by everyone.

So I will get back to you to make sure that I am not giving you misinformation. But, I am certain that is not a termination activity, so we don't run into the same problem.

ANTIDEFICIENCY ACT PROSECUTIONS

Mr. ADERHOLT. The Antideficiency Act in itself, predecessor statutes have been in existence for about 120 years, do you know how many people have been prosecuted under it?

General BOLDEN. Sir, I do not. But I was told that there have been some. And that if I did not want to be among the few, then I should take it seriously. I can find out for you, sir. And I will make——

ANTIDEFICIENCY ACT

NASA does not have specific information as to prosecutions under the Antideficiency Act. NASA is required to and intends to comply with all laws, including the referenced provision of the FY 2010 Appropriations Act.

Mr. ADERHOLT. We were told that there is none that have been——

General BOLDEN. Under Antideficiency Act?

Mr. ADERHOLT. That is what we have been told. Now, again, we will—maybe you need to check the record on that. That is according to a book, The Antideficiency Act Answer Book that was published back in 2009, that—a book by William G. Arnold. But, again, we——

General BOLDEN. If that is the case, there are two of us I know in NASA who would be—although as Congressman Wolf mentioned, we could be the first. But Doug Cooke, my Exploration Systems Mission Director, and me, we would be very relieved to find that nobody uses that Act. I am told that it has been around.

Mr. ADERHOLT. Well, we will certainly need to verify that. Of course, like I said, this is—this was something that was written. And, of course, as you know anything that always is published is not always true.

General BOLDEN. Yes, sir.

Mr. ADERHOLT. Congress has not specifically told NASA not to terminate those programs. And yet in the case of Constellation you can hardly be blamed for the Antideficiency Act's actions since Congress has specifically told you not to terminate these programs.

CONSTELLATION PROGRAM CONTRACT MODIFICATIONS

The rumor was that the head of contracting at NASA was in the process of explicitly inserting a clause in the Constellation contract to advise the contractors that NASA would cover termination costs but was told to stop last fall. Is there any validity to that?

General BOLDEN. Sir, I will have to get back to you on that. I do not know the answer.

Mr. ADERHOLT. But you could check that and let me know?

General BOLDEN. I can find out.

Mr. ADERHOLT. Okay.

General BOLDEN. And so I make sure that I understand the question, did the contract manager—did the COTaR issue a letter advising them——

Mr. ADERHOLT. Explicitly, yes, sir, in a clause in the Constellation contracts by the contractors that NASA would cover contract termination costs but was told to stop.

General BOLDEN. I will get back and get that information for the record.

CONSTELLATION—ANTIDEFICIENCY ACT

That is not correct. There was no direction to stop processing this clause in the fall of 2009. In fact, this clause was inserted in the Boeing Avionics and Upper Stage contracts on January 21, 2010, and January 25, 2010, respectively. Upon learning that the President's proposed FY 2011 budget request on February 1, 2010, proposes to cancel the Constellation Program, the Head of Procurement at NASA determined that NASA would not pursue adding this clause to other NASA contracts.

The activity that was ongoing relative to a termination liability clause during this time period was the investigation by NASA personnel as to whether to incorporate into NASA procurement regulations a special termination liability cost clause similar to the one utilized by the Department of Defense. These types of special termination liability cost clauses generally delineate that potential termination liability costs will not be funded on the contract; **the identification of funds to cover potential termination costs**; and the maximum amount of termination liability under the contract. Incorporation of such a clause into NASA procurement regulations is not imminent.

ARES V COST

Mr. ADERHOLT. Okay. We have heard a lot about inflated numbers, about how much it will cost to complete the Constellation Program, including the heavy lift of Ares V, which I mentioned.

My understanding is that NASA's estimate in the spring of last year for developing Ares V was about—that by 2020 through the first part of Ares V, the cost of development plus production costs, would be $16.5 billion.

If Ares I is not completed, which means we could not benefit from the way the two programs were designed to use some of the same technology, then the fact would result in a cost of Ares V of about $27 billion.

Our staff were told last Friday by the CFO that the cost of developing a heavy lift rocket would be $30 to $50 billion. What engineering data would you—have you obtained since the spring of 2009, which leads to the incredibly inflated figure of $50 billion?

General BOLDEN. Congressman, I will have to get back to you for entry into the record. I was not aware of that figure.

HEAVY-LIFT CAPABILITY

NASA has not established a formal cost estimate for Ares V, nor has NASA established a formal cost estimate for a similar heavy-lift capability. Additionally, no additional engineering data has been obtained to influence these cost estimates. However, the Agency has developed rough, preliminary estimates for Ares V costs—estimates that vary based depending on which assumptions (i.e. schedule, budget year, shared costs etc.) are included in an estimate. Therefore, comparing one cost estimate against another can lead to a misunderstanding if the assumptions are not standardized or fully understood.

With regard to the $30–50B figure cited by NASA's Chief Financial Officer, NASA would like to clarify that those numbers are most closely related to the Ares V project and are rough cost estimates, based on varying assumptions. Based on preliminary Agency estimates, NASA anticipates that the Ares V project costs, through 2020, including development and early production, would be $27B—similar to the $30B ballpark figure cited at hearing. The $50B estimate cited is comparable to Ares V costs, including development and early production through 2025—again, if Ares I were cancelled. However, none of the aforementioned estimates include any of the supporting elements required for launch, such as ground facilities, mission control, and program integration, or any payload. Those costs would be additional. (Note: Ares I and V share substantial development and fixed costs such as shared hardware, which must be considered in any estimate for one vehicle without the other. Therefore, if Ares I were continued, Ares V project costs through 2020, including development and early production would be around $16.5B.

With regard to cost estimates for heavy-lift, it is difficult to provide an accurate estimate given that this estimate would depend on type of vehicle chosen and its capabilities, among many other things. Such an estimate also would depend greatly on the phasing of funds available. However, NASA believes that cost savings could be realized by developing a heavy-lift vehicle that could be used by multiple users (EELV, commercial, other Government agencies.) As such, multiple users of the same vehicle would likely lower the overall lifecycle cost through higher production rates.

Mr. ADERHOLT. Okay. That is all I have for right now.

Mr. MOLLOHAN. Mr. Fattah.

NASA BUDGET INCREASE

Mr. FATTAH. Thank you, Mr. Chairman.

Administrator Bolden, I am very pleased to have you before the Committee, and your extraordinary record of achievement, and leadership now of one of the finest agencies in the government. I think that NASA brings a great deal of inspiration to Americans because of the work that is being done and that has been done.

I just want to walk through a couple of things. You know, we have a major deficit in the government now and a national debt that is growing. There is a lot of discussions about cuts in programs.

But in terms of NASA, it is true for the record, that this is an increase. This request is an increase in your budget. Is that accurate?

General BOLDEN. That's correct, sir.

ASTROPHYSICS

Mr. FATTAH. Now one of the areas that I have some interest in is in astrophysics, your observatory program, because it really I think is kind of like at the vanguard of creating the dynamics under which further exploration, even human exploration, could go forward under.

So you have a request for over the allowance in astrophysics. Is that for your existing 14 observatories and what else?

General BOLDEN. Sir, I will get back to you for the record with what the funds are specifically identified for.

Mr. FATTAH. Okay.

General BOLDEN. There is a number of different projects and programs. And I will get that to you for the record.

ASTROPHYSICS

In Astrophysics, NASA is discovering how the universe works, exploring how the universe began and developed into its present form, and searching for Earth-like planets. The Agency's Astrophysics Theme has an integrated strategy, supported by the 14 operating missions noted, plus a robust research program, and 10 flight projects in various stages of planning and development.

The overall increase in the FY 2011 NASA budget request for Astrophysics (as compared to the FY 2010 request) is due primarily to the selection of the Gravity and Extreme Magnetism (GEMS) Explorer mission, funded with a transfer from the Heliophysics budget to the Astrophysics budget. The Explorer Program is shared by the Heliophysics and Astrophysics Themes, and the Heliophysics Theme transfers budget to the Astrophysics Division when an Astrophysics Explorer mission is selected. The FY 2011 and FY 2010 budget request and runout for Astrophysics is below.

[Dollars in millions]

	FY 11	FY 12	FY 13	FY 14	FY 15
FY 2011 NASA Budget Request	1,076.3	1,109.3	1,149.1	1,158.7	1,131.6

[Dollars in millions]

	FY 10	FY 11	FY 12	FY 13	FY 14
FY 2010 NASA Budget Request	1,120.9	1,074.1	1,042.7	1,126.3	1,139.6

The FY 2011 budget request for Science includes $1,076.3M for Astrophysics. The golden age of Astrophysics from space continues, with 14 observatories in operation. Astrophysics research, technology investments, and missions aim to understand how the universe works, how galaxies, stars and planets originated and developed over cosmic time, and whether Earth-like planets—and possibly life—exist elsewhere in the cosmos. The NASA Kepler telescope has discovered five exoplanets, ranging in size from Neptune to larger than Jupiter, demonstrating that the telescope is functioning as intended; additional discoveries are anticipated in the coming months and years. NASA's newest space observatory, WISE (Wide-Field Infrared Explorer), has captured its first look at the starry sky and its sky survey in infrared light has begun. Radio astronomers have uncovered 17 millisecond pulsars in our galaxy by studying unknown high-energy sources detected by the Fermi Gamma-ray Space Telescope.

The Hubble Space Telescope is operating at its peak performance thanks to the very successful servicing mission last year by the STS–125 crew. The Herschel and

Planck missions, led by the European Space Agency with NASA as a partner, were launched in 2009 and are returning remarkable scientific results. In FY 2011, NASA will complete most of the development of the NuSTAR mission and prepare it for launch. NASA will also begin developing the Gravity and Extreme Magnetism (GEMS) mission recently selected in the Explorer small satellite program. The James Webb Space Telescope (JWST) continues to make good progress in development toward a 2014 launch. Flight hardware for the many JWST subsystems is being designed, manufactured and tested, including the 18 segments of its 6.5-meter primary mirror; and the mission-level Critical Design Review for JWST will occur this spring. The SOFIA airborne observatory successfully conducted its first open-door flight test in December 2009—a major milestone toward the beginning of early science operations this year.

The NRC is conducting a new Decadal Survey in astronomy and astrophysics, which will set priorities among future mission concepts across the full spectrum of Astrophysics, including dark energy, gravity wave, and planet-finding missions. The "Astro2010" Decadal Survey is expected by September.

MIDDLE SCHOOL EDUCATION EFFORTS

Mr. FATTAH. Okay. And I also want to commend you for the requests related to the education efforts in middle school and the budget is $445 million.

The Chairman has been quite supportive of NASA. And the Subcommittee always follows his lead. So I am sure that you will have, after a detailed examination, a very favorable consideration for your request.

SPACE SUMMIT

And I want to thank you for your great leadership. Now the President is coming to host a summit of sorts, a space exploration process. Is there anything you can tell the Committee about what is expected?

General BOLDEN. Sir, it is still in the works. It is in the early stage of planning. It is intended to be a space conference to be held in Florida where the President and members of Congress will participate.

The primary purpose for the President, is to allow him to provide his vision to the nation and the world actually. Also to allow him to have an opportunity, which he has not so far, to at least see some of the facilities at the Kennedy Space Center and hopefully talk to some of the workers and the like.

Mr. FATTAH. Has there been an occasion on which this has happened in the past to your knowledge that——

General BOLDEN. There have been visits to the Kennedy Space Center——

Mr. FATTAH. Walk-throughs, right?

General BOLDEN [continuing]. By past Presidents. I don't know that there has ever been a President who has taken the opportunity to travel there to have a conference on space. I know there has never been a President who has had the challenge of trying to promote exploration and human space flight at a time that is more challenging fiscally.

Mr. FATTAH. Well the fiscal challenge is obvious. And that is why the Administration really ought to be commended inasmuch as making a submission that would call for an increase in exploration.

So I want to commend you, and OMB, and the Administration for seeing the importance of exploration. And, again, I am interested in the details on the astrophysics program.

General BOLDEN. Yes, sir. I will get that for you and get it to you personally. And then make it an entry for the record.

Mr. FATTAH. Thank you.

Mr. MOLLOHAN. Thank you, Mr. Fattah.

Mr. Wolf, do you have any questions?

HEAVY-LIFT CONTRACT

Mr. WOLF. I do, thank you. Thank you, Mr. Chairman.

When do you see NASA issuing a contract for heavy-lift system?

General BOLDEN. Congressman, I don't have a date, because I have a heavy lift launch vehicle team that is looking at the path that we should take to get there. I can tell you that we are probably years away from identifying a specific architecture, because the architecture on which we settle will be greatly dependent upon what we learn from the technology development efforts that we are going to do using the International Space Station, using other vehicles, and using some of our research. So the architecture itself won't be defined until we find out what capabilities or what technological capabilities we have today, which are different from what we had when the Constellation Program was originally envisioned.

SHUTTLE WORKFORCE TRANSITION STRATEGY REPORT

Mr. WOLF. Fiscal year 2008 Appropriation Bill requires NASA to issue a report on shuttle workforce loss every six months. NASA has not updated this report for nearly a year. When will that be updated?

General BOLDEN. Sir, we are going to actually provide a preliminary report this coming May that will not be the full workforce report as required. We hope to have that one completed by August.

And, again, I must take the blame, because that particular report, as you all asked for, is supposed to give a detailed estimate in terms of numbers of people and the like and how we plan to transition them.

When I came in to my position, things were in flux, and we just did not feel that we had enough facts about where the workforce was going to be down the road given the questions about NASA's direction. That is why we did not provide one recently. But hopefully it will be available in August.

Mr. WOLF. I don't think there is a criminal penalty for that one I don't think. But the Chairman's done a lot of good work on prison reform. Well, if you could, I think it is important.

General BOLDEN. If there had been a criminal penalty for that, I probably would have had to suffer the penalty, because I just did not have the information to adequately put together the report, and we are working diligently to try to do that in August.

Mr. WOLF. How long has it been since there has been a report? When was the last report?

General BOLDEN. I think the last one, when I looked a couple of days ago, I will get back to you for sure. But it was—we did one in 2009 I think. I will look and try to find it.

PRIMACY IN SPOKE

And, sir, may I offer an apology to you. It has bothered me. When I responded to your question on China in the moment, it does make a difference to me who is first. And I think in my exuberance I said something that I didn't mean. You know, it is important that we be first all the time. I am extremely competitive. And so I apologize to you for making what was a flip statement to be quite honest.

Mr. WOLF. Well let me ask unanimous consent that your apology be taken and you go back and we take out what was said the first time, Mr. Chairman, if we can.

General BOLDEN. Mr. Chairman, I appreciate that, sir.

Mr. WOLF. Yes, I think we should do that.

General BOLDEN. I appreciate that. But I should have spoken——

Mr. WOLF. Sure. I ask unanimous consent, Mr. Chairman, that the first comment be taken out. And you give me your position for the record. You submit it for the record.

MOON—UNITED STATES VERSUS CHINA

The United States is and should be proud of being the first and only nation to land a human on the Moon and should we choose to go to the Moon on a priority basis, because of where we are technologically in comparison to China, I think that the United States would get back there first. However, the President's vision for space exploration enables a set of stepping stones that I believe will take us further and faster into space, allowing us to reach a range of destinations including lunar orbit, Lagrange points, near-Earth asteroids, the moons of Mars and eventually Mars itself.

Mr. MOLLOHAN. We will look at that carefully and excise it as appropriate.

CONSTELLATION PROGRAM CONTINUITY

Mr. WOLF. Thank you, Mr. Chairman. If part or all the Constellation Program ends up being restored by Congress, can we be assured that the actions you are taking this year will not unnecessarily hamper or delay the continuity of the program?

Mr. MOLLOHAN. Pardon me for yielding. I have a 5:15 meeting, which I have to attend. Mr. Wolf, I would like to extend my appreciation for the General testifying here today, for his hard work and that of all his employees. And we look forward to working with you.

I will leave you to the tender mercies of Mr. Wolf. And I will yield the Chair to my good friend and colleague Mr. Fattah. Thank you very much for your testimony today. Mr. Wolf, thank you for yielding.

Mr. WOLF. To repeat, if part or all the Constellation Program ended up being restored by Congress, can we be assured that the actions you are taking this year will not unnecessarily hamper or delay the continuity of the program?

General BOLDEN. Well, sir, I can assure you of that. In fact, the only action that we have taken that I mentioned earlier in stopping procurement activities that would have brought us to a contract competition, those are all procurement activities that can be restarted at any time. So there would be no break.

CONSTELLATION CLOSEOUT COST

Mr. WOLF. Okay. Your budget describes tiger teams that will assess workforce procurement and other closeout issues over the coming months. If these issues have not yet been fully assessed, what confidence do you have that 2.5 billion is an accurate estimate of closeout costs?

General BOLDEN. Sir, that is the best estimate that we could come up with. And as always, you are hoping that you have made a very conservative estimate and that it won't be anywhere close to that.

We looked at past program closeouts and we looked at what was in the Constellation Program. There are other factors that were taken into consideration that I don't remember. But I can get that back to you. But I am hoping that that is a conservative number.

Mr. WOLF. Okay.

General BOLDEN. Sir, you asked about the Workforce Transition Strategy Report.

Mr. WOLF. Right.

General BOLDEN. The last time we sent one was in July of 2009.

PLUTONIUM-238 PRODUCTION

Mr. WOLF. July of 2009. I recently talked with Steve Squyres, the lead scientist on the Mars Rover Program. He had serious concerns about the President's new plan. But also raised another area of concern with solar system science and exploration. And that is the availability of plutonium-238 to power a spacecraft.

I understand that the fiscal year 2011 budget includes funding to restart plutonium-238 production. Can you describe the need for this, how much money is in the budget, and whether other alternatives exist, and what the plan is for restarting the production?

General BOLDEN. Sir, we have as recently as this past week been involved in discussions with OMB, the Department of Energy, on what is the actual future need for plutonium-238. We have agreed that we will pay a portion of whatever the cost for that production is. We really are just interested in getting the production restarted.

And I think the other question you asked was when would we start and how much would we pay.

Mr. WOLF. Right.

General BOLDEN. And those answers I will get for the record.

PLUTONIUM-238 PRODUCTION

NASA has always worked with the Department of Energy (DOE) to acquire the plutonium-238 we need to fuel the radioisotope power systems that enable many of our most demanding planetary missions. DOE and its predecessor agencies have the legislative mandate to ensure the national needs for Pu-238 are met and they have been producing radioisotope power systems for nearly fifty years. Radioisotope power systems uniquely enable missions that require a long-term, unattended source of heat and/or supply of electrical power in harsh and remote environments. These systems are reliable, maintenance free, and capable of producing heat or electricity for decades. The plutonium-238 in these units serves as the source for generating heat and electricity.

In the past, Pu-238 was produced at DOE's Savannah River Site in South Carolina, using reactors that are no longer operating. The last operating reactor was shut down in 1996. After DOE stopped producing Pu-238, DOE made use of its limited, existing Pu-238 inventory to supply power systems to user agencies. Beginning in 1992, this inventory was augmented by Pu-238 purchased from Russia for peaceful applications to fuel power sources that provide heat and electricity for NASA missions. However, the agreement to purchase this Russian material was recently defaulted upon by the Russian government. Although DOE is pursuing a new agreement under new terms with the Russians for this material, such an arrangement will always be a risk to NASA missions. DOE plans to return to Russia in May 2010 to attempt to negotiate a resumption of planned purchases from Russia to continue to fill the gap until U.S. domestic production can be restored at a rate that will meet our future national needs.

It is imperative that the funding requested in the President's FY 2011 budget request for restarting domestic production of Pu-238 be approved by Congress. Specifically, $30M is included in the President's request, evenly divided with $15M in the DOE's budget request, and $15M in NASA's budget request. It is planned that DOE and NASA will share in the capital cost of reestablishing a domestic production capability. Although NASA is expected to be a primary user of Pu-238 produced in the near future, this capability will also be available to support future national security applications, if needed. DOE's share in the capital costs is consistent with the Department's mission to maintain a national capability for a range of potential Federal users.

In short, a new Pu-238 production capability is required to maintain Radioisotope Power Systems as an important national capability. Because of dwindling stockpile of existing Pu-238, and the long lead-time associated with reestablishing a domestic production capability (as much as 6–8 years), DOE is working, in coordination with user agencies, to reestablish Pu-238 production at a rate sufficient to support both NASA and potentially other missions. Based upon NASA's requirements, we believe that a production rate of 1 to 2 kg per year is sufficient for the foreseeable future. This rate can be accomplished using known technology and similar existing National Laboratory capabilities to produce and separate Pu-238.

This approach minimizes the necessary startup investment, and provides the most rapid initial production of Pu-238, which is necessary to meet NASA's mission requirements.

DOE and NASA are preparing a restart plan that will provide additional details. We expect to provide that restart plan to the Subcommittee in the near future.

DOE and NASA are also working together to ensure needed purchases from Russia are completed to ensure an adequate supply of Pu-238 to avoid delaying future NASA missions, including a major Outer Planets Mission. This additional plutonium is necessary to retire any mission risk due to the schedule of re-establishing U.S. production capability in meeting mission requirements. There are no other alternative materials or energy sources appropriate for deep space missions other than purchasing Pu-238 from Russia or restarting domestic production. The potential impact on future missions from delay in restarting domestic production is, NASA believes, what Dr. Squyres may have been referring to.

NASA has requested FY 2011 appropriations language that instructs NASA to partially fund restart of DOE production infrastructure and direct all the necessary NASA to DOE funds transfers. NASA recommends that Congress provide this direction in the FY 2011 appropriation and has submitted as part of its FY 2011 budget request proposed appropriations language that would accomplish this. This inclusion will avoid inadvertently creating additional National Environmental Protection Act (NEPA) review requirements and/or litigation risk by requiring a discretionary NASA funding decision to support this project. Formal arrangements to be established under an existing DOE/NASA memorandum of understanding (MOU) would also need to be consistent with this approach. If approved, NASA will work closely with DOE to ensure that the appropriate steps are taken to ensure a timely restart of domestic Pu-238 production.

Mr. WOLF. And whether other alternatives exist.

General BOLDEN. Sir, one of the alternatives that we are trying to avoid is buying it from Russia.

Mr. WOLF. Okay. Yes, I would agree with that.

On education, I congratulate you on identifying education as important. Well, let me go back to the Squyres issue too. Have you spoken to Steve Squyres since

General BOLDEN. Sir, I have not, and I was not aware of his concern, but that has not been an issue with us. We understand what amount of plutonium-238 is necessary for us, and that we have looked at our programs and future projects, and what we have stated we need is sufficient for the programs that we have on the books. I was surprised that someone feels that we need more.

Mr. WOLF. Yes, he had some serious concerns. I would also suggest there are about four, or five, or six people, which I am not going to give you. I can give you off the record. But I really think it would be helpful for you just to call. I mean, you know, everyone has—you know, when I try to make a tough decision on something, I try to call people who don't necessarily agree with me. But I just want to kind of honestly get their best wisdom. The Bible talks about wisdom and the judgment of wise men.

I had a conversation with him. He is someone I think you ought to talk to about this and about the overall program. But I learned a lot from him.

I know you are busy. But I think just to have a conversation with him on the phone or the next time he is Washington. You know, he comes in here periodically. Just to sit down and just to get four or five people like that together.

But about the plutonium-238, because he expressed some deep concerns.

General BOLDEN. Sir, I will go back and review it with my directorates, and also talk to Mr. Squyres, and then get back to you, because I was not aware. I am not aware of any shortage that we anticipate.

Mr. WOLF. Okay. And we wanted to give you a letter but maybe we won't. We will just wait to hear from you.

General BOLDEN. Yes, sir.

EDUCATION BUDGET

Mr. WOLF. On the education, I appreciate your identifying education as an important priority for NASA. Shortly after you came aboard, you came to talk to me about your Summer Innovation Initiative. And I think one of the greatest benefits of NASA to our society is the inspiration and excitement it provides for young people.

Yet the budget request for education is actually a reduction of almost $40 million to 21 percent from the current level.

General BOLDEN. Sir, in the budget that I received, we had a $20 million annual plus-up. You are the second person that has said I have a reduction in my budget. I will go back and check for the record. But I think someone may have been looking at grants from the Department of Education.

Mr. WOLF. Mr. English said that it went from 180 to 140, which was actually a reduction.

General BOLDEN. I will go back and double check and then get back to you for the record.

Mr. WOLF. Okay. If we could do that and then let us know.

Mr. Chairman, I have just one or two other questions. We will submit the others.

Mr. FATTAH. Will the gentlemen yield for a second? We have an answer on the education budget.

Mr. WOLF. Okay.

Mr. FATTAH. It is an increase over the request that was made from last year. And it is down from what we actually appropriated last year.

Mr. WOLF. Okay. So there are a number of plus-ups.

Mr. FATTAH. No. These are not—they are separate. They made a request last year.

Mr. WOLF. The overall level was plus-up.

Mr. FATTAH. Right.

Mr. WOLF. Okay.

General BOLDEN. Thank you very much.

Mr. WOLF. Okay.

General BOLDEN. That is the answer I just——

Mr. WOLF. Well he is from Philadelphia.

Mr. FATTAH. And so is my Ranking Member.

Mr. WOLF. Yes.

Mr. FATTAH. And the former Chair of this Committee and also a big booster of NASA.

BUYING RUSSIAN LAUNCH SERVICES

Mr. WOLF. After the retirement of the shuttle, you will need to buy flights from Russia to deliver the crew to the station. Have you secured the necessary agreements with the Russians? And to combine the next question, what are the costs, and how do the costs compare with those in previous agreements with Russia? Do you have an agreement, and what are the costs, and how do the costs compare?

General BOLDEN. Sir, the existing contract right now I think it is $51 million, which includes training and transportation. It is a lot of different things. I will have to get back to you for the record as to what it was on the previous contract.

RUSSIAN SUPPORT TO NASA

NASA purchases comprehensive Soyuz support from Russia, including all necessary training and preparation for launch, crew rescue and landing for an entire long-duration mission. This support includes training and Soyuz seat certification, individual equipment, medical checks, supplies, on-orbit consumables, and search and rescue services. NASA does not purchase launches or Soyuz spacecraft themselves, but rather round trip "seats" or crew rotations, which incorporate all the associated services outlined above. For the contract extension signed between NASA and Roscosmos on April 2, 2010, these services amount to an average of $55.8 million for each crew member rotation purchased in 2013–2014. For the previous contract extension signed between NASA and Roscosmos on May 28, 2009, these services amounted to an average of $51M for each crew member rotation purchased.

The question was not asked. But I feel compelled to say that the primary means of getting humans to the International Space Station, the expedition crews for a number of years by agreement among the international partners has been Soyuz. So while it will seem that we are doing something different, because we don't have shuttles anymore, we use shuttles to get equipment and components, large components back and forth. But not as the primary means of getting crew there.

Before I came, the agreement among the international partners was that we would use Soyuz as the primary means to get crews there and the primary means to get them back. And that is the only rescue vehicle that we have ever had from the beginning of the International Space Station Program, because back then we as a nation decided that we did not want to follow through on the production of a crew rescue vehicle.

So the international partners again came together and decided if the United States is not going to provide it, then the next best thing is a Russian Soyuz. So today, two Soyuz, well one, because we only have a slight crew there, but whenever there is a full crew there, there are two Soyuz spacecraft that are there to bring the crews back in the event of an emergency.

Mr. WOLF. What are the costs now? And do you have any agreement as to what the costs will be?

General BOLDEN. I was saying the cost now is I think $51 million.

Mr. WOLF. Fifty one million and do you expect that to increase?

General BOLDEN. Sir, I do not. In fact, I do not expect it to increase significantly. We are in negotiations right now for a follow-on contract. If everything works out really well and one of the commercial entities that says they can get us to the International Space Station by 2013, it would not be necessary for me to renew the contract. But at the Heads of Agency meeting, the Russians said that they did not foresee a significant increase in the cost.

Mr. WOLF. Okay.

General BOLDEN. They talked about it in terms of inflation.

COMMERCIAL CARGO AND CREW CAPABILITIES

Mr. WOLF. Well the last question leads to just really where you were. The COTS Program is your attempt to develop and procure private sector capabilities, SpaceX and Orbital, to resupply the International Space Station.

The fiscal year 2011 puts an additional $6 billion over five years. What is the current status of these efforts? And what is the earliest that the commercial cargo and crew capabilities to this space station could be operational?

General BOLDEN. Congressman, under the current schedule, they are planning to take crew to the International Space Station by 2015. Both intend to fly their first COTS missions from—I think SpaceX is February of 2011 and then Orbital, May of 2011. I will add that was just the first round of commercial vendors. We are about to enter into another competition where we are hoping to increase the number of potential providers of commercial transportation. And among those, we expect that there will be some of the very well known providers of launch services to this date. While it is too early for me to announce something for a ULA, the information is that they or their partners do intend to bid in the next round.

RANKING MEMBER CLOSING REMARKS

Mr. WOLF. I would end just to say since there is strong opposition, I do worry about a series of lobbyists rolling in here who, you know, plan on making a lot of money without worrying about where we are vis-a-vis the Nation.

I think it would be helpful to—and I know no one wants to back down. No one wants to get into these things. But I did work for a Cabinet Secretary. And I think sometimes when you have something like this, this is very important. I mean, this is one area that we are ahead of everyone else. This is an area that has the imagination. I hear the President talking about getting young people involved.

We just had the gentleman yesterday, Neil deGrasse Tyson. Have you spoken to him recently?

General BOLDEN. Oh, yes, sir.

Mr. WOLF. How recently have you spoken to him?

General BOLDEN. I think the last time was about two weeks ago. It was at the last shuttle.

Mr. WOLF. Okay, yes.

General BOLDEN. And he is an incredible human being.

Mr. WOLF. Yes. And so I think it would be helpful to get a group of people like him, and Squyres, and some of the others, which we can give you the names, and just bring them in and sort of say, you know, where do we go from here? There are some good things in there.

But I really worry at times that—and I know the President has got a lot on his mind. He has got other things going on. We have a budget deficit. We got a war in Afghanistan. We got a war in Iraq. And there are a lot of things going on.

But I think it would be helpful with the spirit of reconciliation, not to use the reconciliation that you are talking about in the Congress, but reconciliation from a biblical sense, if you will.

Bring a group of people in and take a day or two to sit around and really think about this, because the decisions that are made are going to have so many impacts, whether it be with foreign nations, whether it be with stimulating that young kid at Patterson Elementary that is going to want to know if he gets into science. I mean, this is really important.

And I do worry a little bit about every administration that puts something out there. They really almost consider it a challenge to them if anyone wants to kind of change anything.

And I know being a Cabinet Secretary, as you are a Cabinet Secretary, your obligation is to advocate for the Administration for a proposal. If you don't, then, you know, you should leave and let someone else do it. But I think within the confines of that.

So I would encourage you, we will give you some names, to pull together some of these people and take a good period to see if we can come up with something whereby we resolve a lot of the issues, that you understand certainly better than I understand, that are out there. And so if you would do that, I would——

General BOLDEN. I appreciate that recommendation. We will do that. I will tell you, the President needs no defense. But he is engaged in space policy. I spent a half hour this morning, not with him but with the Deputy Chief of Staff, because he is engaged. He has promised that we are going to find a solution to this problem. He has stated that, or through his Deputy Chief of Staff, he has stated that we are going to find a way to come together, because it is important for the nation. I agree with you, and the President does also.

Mr. WOLF. Okay.

General BOLDEN. I don't think it is a matter of anybody backing down. I think it is a matter of us trying to find common ground in what is an incredible budget. But what may be just differences of opinion that people have. I am confident that we are going to find a solution that will be good, because no one will be happy.

Mr. WOLF. Okay. Thank you, Mr. Chairman.

CONGRESSMAN FATTAH CLOSING REMARKS

Mr. FATTAH. Let me thank my colleague who is also from Philadelphia. Now we are going to wrap up. And it has been an honor to have you present to the Committee. And the Chairman made his—made the point that he had an appointment that he had to go to.

But we appreciate your leadership. And I think the country will be excited to witness the Space Exploration Meeting that the President is coming to lead and to listen. And we are going to learn a lot more about the vision. And I think here a host of views and the choice points that have to be kind of thought through.

So thank you very much and have a good day.

General BOLDEN. Congressman, thank you also very much. I appreciate the time you have given us. And I know you didn't have to take all this time. But I appreciate it. Thank you.

Mr. FATTAH. Thank you.

Chairman Alan Mollohan
Questions for the Record

NASA Mission

1. **What are the missions of NASA as authorized in the Space Act as amended?**

   Answer: The following excerpts from the National Aeronautics and Space Act of 1958, as amended, outline the missions of NASA.

   DECLARATION OF POLICY AND PURPOSE (42 U.S.C. 2451)
   Sec. 102. (a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

   (b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities.
   The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 2471(e).

   (c) The Congress declares that the general welfare of the United States requires that the National Aeronautics and Space Administration (as established by title II of this Act) seek and encourage, to the maximum extent possible, the fullest commercial use of space.

   (d) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

   (1) The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space;
   (2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;
   (3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;
   (4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific

purposes;
(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;
(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;
(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof;
(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment; and
(9) The preservation of the United States preeminent position in aeronautics and space through research and technology development related to associated manufacturing processes.

(e) The Congress declares that the general welfare of the United States requires that the unique competence in scientific and engineering systems of the National Aeronautics and Space Administration also be directed toward ground propulsion systems research and development. Such development shall be conducted so as to contribute to the objectives of developing energy- and petroleum-conserving ground propulsion systems, and of minimizing the environmental degradation caused by such systems.

(f) The Congress declares that the general welfare of the United States requires that the unique competence of the National Aeronautics and Space Administration in science and engineering systems be directed to assisting in bioengineering research, development, and demonstration programs designed to alleviate and minimize the effects of disability.

(g) The Congress declares that the general welfare and security of the United States require that the unique competence of the National Aeronautics and Space Administration be directed to detecting, tracking, cataloging, and characterizing near-Earth asteroids and comets in order to provide warning and mitigation of the potential hazard of such near-Earth objects to the Earth.

(h) It is the purpose of this Act to carry out and effectuate the policies declared in subsections (a), (b), (c), (d), (e), (f), and (g).

FUNCTIONS OF THE ADMINISTRATION (42 U.S.C. 2473)

Sec. 203.

(a) The Administration, in order to carry out the purpose of this Act, shall--
(1) plan, direct, and conduct aeronautical and space activities;
(2) arrange for participation by the scientific community in planning scientific measurements and observations to be made through use of aeronautical and space vehicles, and conduct or arrange for the conduct of such measurements and observations;
(3) provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof;
(4) seek and encourage, to the maximum extent possible, the fullest commercial use of space; and
(5) encourage and provide for Federal Government use of commercially provided space services and hardware, consistent with the requirements of the Federal Government.

(b) (1) The Administration shall, to the extent of appropriated funds, initiate, support, and carry out such research, development, demonstration, and other related activities in ground propulsion technologies as are provided for in sections 4 through 10 of the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976.
(2) The Administration shall initiate, support, and carry out such research, development, demonstrations, and other related activities in solar heating and cooling technologies (to the extent that funds are appropriated therefor) as are provided for in sections 5, 6, and 9 of the Solar Heating and Cooling Demonstration Act of 1974.

Animal Experimentation

2. There have been four decades of federally-funded space radiation research involving the use of live nonhuman primates. This research ended in 1990 because it failed to advance the safety aspects of human space travel. In fact, a summary report of three decades of this research concluded that:

"[T]he many controlled experiments on animals suffer from the basic fact that the data obtained from animals pertains to those animals, and specifically to them under the exact conditions of the experimental design. The injudicious extrapolation of animal data to provide predictions of effects in humans is probably more hazardous to the future benefits of nuclear medicine than the hazards from the radiations themselves.

NASA recently awarded a $1.75 million grant for a new study that involves irradiating live squirrel monkeys and then testing them to see how they perform on various tasks. What has caused NASA to reassess and resume a proven invalid methodology?

Answer: NASA's proposed research study regarding squirrel monkeys will study the long-term effects of space radiation in non-human primates. The study was selected for funding using a rigorous, independent peer review process, is considered necessary to understand the effects radiation will have on crewmembers who will participate in long-duration spaceflight beyond low-Earth orbit. However, to clarify, while NASA has selected the study for award, NASA has not made the final award.

Given the priority placed on astronaut health, this NASA research study will focus on one of the largest unknowns facing human exploration: the effect of space radiation on an astronaut's central nervous system (CNS). Only in very limited cases can previous NASA research involving mice and rats be extrapolated to humans, and there is no information regarding the effects of space radiation on CNS function in non-human primates. This research is necessary for NASA to develop radiation exposure limits and, if necessary, mitigation strategies for missions within the solar system and for long-duration stays in LEO. The study will help NASA protect crewmembers by setting radiation exposure standards, determining acceptable time limits that astronauts can be in space, and enabling spacecraft designers to incorporate effective shielding technologies.

NASA, and the scientific community it supports, has long recognized its responsibility to treat laboratory animals humanely and to house and care for them properly. NASA well recognizes that only significant and necessary research should be performed on animals and such studies should be minimized. The Agency carefully follows all Federal Government laws and policies regarding the care and use of animals in research, including reviews by appropriate institutional animal care and use committees.

Furthermore, NASA has also developed and continuously implements its own additional rules and processes to further ensure the humane treatment of any animal involved in NASA-sponsored research, both in NASA ground-based laboratories and in manned and unmanned space flights. Specifically, NASA adheres to the animal welfare principles articulated in the "NASA Principles for the Ethical Care and Use of Animals." These principles, which are modeled after those created for the use of humans in research, were created in 1996 by a panel of bioethicists and animal welfare experts, as well as representatives from the American Society for the Prevention of Cruelty to Animals and the Humane Society of the United States. In the case of this proposed study, review by biomedical ethicists and technical experts concluded that the study follows the NASA guidelines.

Astronaut Transport to Low Earth Orbit (LEO)

3. **NASA currently purchases seats for our astronauts on the Russian Soyuz at $51 million per seat and plans to continue this for some years to come. What will Russia likely charge in the future, and how does this factor into the proposed plan to fund development of a US astronaut transport to LEO capability?**

   Answer: NASA's agreement with the Russian Federal Space Agency, Roscosmos, defines the services and factors that affect the price per seat. NASA's contract for Soyuz services includes not only crew transportation but also training, on-orbit crew rescue, recovery and other such services as part of the seat price. The current contract price per seat is $55.8M on average for each crewmember rotation purchased for the 2013 – 2014 period. The average per-seat cost in the previous contract extension was $51M, which covered seat purchases through 2012. Factors that may affect the price per seat include currency exchange rates and inflation in Russia. Negotiations for additional seats in the future could result in increased costs to NASA due to these factors.

4. **As the Space Shuttle program ends and reliance on Soyuz launch services begins, what is the schedule for future US astronaut flights and for astronaut flights for partner nations for which NASA is paying?**

   Answer: To sustain six crewmembers on-board the ISS, four Soyuz flights per year are required. (Four Soyuz flights per year equates to 12 flight opportunities per year). In accordance with Article 11, Space Station Crew, of the bilateral Memoranda Of Understanding (MOUs), flight opportunities (and other ISS resources) for the International Partners are based on their percentage of ISS Partnership (CSA – 2.3 percent, ESA – 8.3 percent, JAXA – 12.8 percent) for the available opportunities. Also based on bilateral MOU's with the Canadian Space Agency (CSA), the European Space Agency (ESA), and the Japanese Aerospace Exploration Agency (JAXA), NASA is required to provide crew transportation for their allocated crewmembers. The Russian Federal Space Agency (Roscosmos) is responsible for accommodating and transporting its crewmembers. Under NASA's MOU with the Italian Space Agency (ASI), Italy's flight opportunities are a subset of the NASA allocation. Based on the current model of a 6-person crew with 6-month missions, the following table shows approximately how many opportunities each IP would earn:

12 Flight Opportunities/year		
Roscosmos	6	
NASA (+ ASI)	4.6	
JAXA	0.768	1/1.3 yrs.
ESA	0.498	1/2 yrs.
CSA	0.138	1/7.2 yrs.

Based on the above allocations, the current baselined crew rotation plan is shown below by agency:

Year - Month	Down	Up	Onboard ISS	# of ISS crew
2010				
March	1-N, 1-R		1-N, 1-R, 1-J	3
April		1-N, 2-R	2-N, 3-R, 1-J	6
June	1-N, 1-R, 1-J		1-N, 2-R	3
June		2-N, 1-R	3-N, 3-R	6
September	1-N, 2-R		2-N, 1-R	3
October		1-N, 2-R	3-N, 3-R	6
November	2-N, 1-R		1-N, 2-R	3
December		1-N, 1-R, 1-E	2-N, 3-R, 1-E	6
2011				
March	1-N, 2-R		1-N, 1-R, 1-E	3
April		1-N, 2-R	2-N, 3-R, 1-E	6
May	1-N, 1-R, 1-E		1-N, 2-R	3
June		1-N, 1-R, 1-J	2-N, 3-R, 1-J	6
September	1-N, 2-R		1-N, 1-R, 1-J	3
October		1-N, 2-R	2-N, 3-R, 1-J	6
November	1-N, 1-R, 1-J		1-N, 2-R	3
Nov/Dec		1-N, 1-R, 1-E	2-N, 3-R, 1-E	6

Note: Indirect crew hand-overs result in a two-week period of 3 person crew onboard ISS.

N - NASA
R - Roscosmos
E - ESA
J - JAXA

5. **Risk is inherent in spaceflight; what are the risk targets for human spaceflight, how are they being systematically reduced, and what are the specific costs and schedules for different improvements?**

Answer: The targets for the Probability of Loss of Crew (LOC) and Loss of Mission (LOM) that were defined in the Constellation Program for a mission to the International Space Station were:

Overall LOC	1 in 270
Overall Ascent LOC	1 in 1000
Overall Entry LOC	1 in 1000
Overall LOM	1 in 55
Orion LOM	1 in 65
Ares 1 LOM	1 in 500

(Reference CxP LOC/LOM Status Presentation, March 2010).

We are continually examining how human spaceflight risks can be reduced by improving the designs and processes that are involved. For commercial human spaceflight activities, we are examining the requirements and oversight that is needed to assure acceptable risks. As these efforts are still in the development stage, we have not yet determined specific costs and schedules for different possible improvements.

6. **Given the projected flight schedule of astronaut launches, what should be the size of the astronaut corps, how does this compare to the current complement of astronauts, and what changes in skill mix and composition are planned?**

Answer: NASA regularly reviews the size and composition of the Astronaut corps, and has been aggressively managing it based upon agency requirements. The active Astronaut corps size has steadily been decreasing over the past 8 years from a peak of 140+ to the 81 currently active in the corps. After completion of the Space Shuttle Program, the corps size target will be in the range of 60-65 active Astronauts. This represents approximately a 53 percent reduction in size from the peak. The Agency is also in the process of requesting that the National Research Council lead an independent study on the role and size of the corps. Increased emphasis has been placed on skills required for long-duration flight, such as Extravehicular Activities, robotics, science, and maintenance of closed-loop life support systems.

7. **Given that training is included in purchased seats for astronaut transportation to orbit, what are NASA's plans for its existing astronaut training facilities?**

   Answer: The purchase of orbital transportation services includes those costs specifically associated with the Soyuz specific training. The majority of astronaut crew training concentrates on generic and ISS mission specific training. Major astronaut training facilities are still needed to support continuing ISS operations (such as the Neutral Buoyancy Laboratory and the full-scale ISS mockups at JSC). These facilities are planned to be retained at a level needed to support training for Extravehicular Activities, robotics, ISS systems maintenance, payloads, science, and other training regimes that are not part of crew transport training, but will be examined within the scope of the NRC study mentioned in answer 6 above.

8. **What are the plans for existing Shuttle astronaut training facilities?**

   Answer: Shuttle-specific training facilities (such as the Full Fuselage Trainer, the Crew Compartment Trainers, and the Fixed and Motion Base Simulators at JSC) will be dispositioned per standard NASA processes, with an emphasis on transferring these facilities to outside organizations to provide educational and public outreach opportunities as appropriate.

9. **Japan, Canada, and Europe are all partners in the International Space Station along with the US and Russia; are any of these partners planning to develop their own astronaut launch capabilities? If they are, what are those plans and what are the prospects for cooperative development of astronaut launch capabilities?**

   Answer: The European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA) have both expressed an interest in upgrading their current autonomous cargo vehicles to downmass-capable vehicles and possibly crewed vehicles.

   During the last ESA Council, ESA was given $40M for a pre-Phase A Study to develop a preliminary design and implement some preliminary activities for a new vehicle, which would first provide cargo downmass. ESA is currently working on a proposed modular design of the ARV (Automated Return Vehicle).

   ESA is currently planning to study an evolution of the cargo transportation system, which could be transformed into a crew transportation vehicle at a later stage and implemented after 2020. ESA has discussed its interest in developing an automated return vehicle based on the ATV, which could serve as a precursor for the development of a European crew transportation system.

Reflecting Japan's commitment to increasing ISS utilization capabilities following the retirement of the Space Shuttle, JAXA recently established a "Space Station Return Office" and is funding initial assessments of H-II Transfer Vehicle (HTV) return capability, which reportedly will include a roadmap for evolving to a crewed vehicle.

10. Given a global economy and the use of components from international suppliers in COTS cargo launch systems, how much non-US content will be permitted in the development of a US commercial astronaut launch system?

Answer: COTS partners will be required to comply with all applicable and appropriate U.S. laws, rules and regulations. Non-US content will be allowed up to the levels prescribed by U.S. law. This is consistent with the practice of the commercial cargo development effort; some of those companies are using international content in their vehicles. NASA is currently developing the commercial transportation acquisition strategy and specific guidance regarding non-U.S. content will be discussed as part of that effort.

11. If astronaut transportation to orbit becomes viewed as a commercial service, how would international trade considerations affect the procurement of such services from commercial providers?

Answer: International trade considerations would not affect the procurement of commercial transportation services. NASA would procure such services from U.S. commercial entities as NASA is required to do pursuant to U.S. Federal law. This is consistent with the U.S. international trade obligations.

The Commercial Space Act of 1998, 42 U.S.C. § 14701 et seq., provides that "the Federal Government shall acquire space transportation services from United States commercial providers whenever such services are required in the course of its activities." 42 U.S.C. § 14731(a). Moreover, current, longstanding U.S. space transportation policy requires that U.S. government departments and agencies shall "...purchase commercially available U.S. space transportation products and services to the maximum extent possible, consistent with mission requirements and applicable law)."

With respect to U.S. international trade obligations related to procurement, NASA is listed as a covered Federal agency under the WTO Agreement on Government Procurement (GPA) and the procurement chapters of our free trade agreements. This means that NASA procurement activities must comply with the requirements under those agreements, unless one of the general exceptions or exclusions applies to a particular procurement contract. The United States excludes transportation services (including launch services) from its government procurement commitments. (See e.g. U.S. Annex 4 to Appendix I of the GPA).

Therefore, the United States has no procurement commitments with respect to these services.

12. Under NASA's proposed program for commercial transport of astronauts to low Earth orbit, are solid rockets candidates?

Answer: Yes. NASA is currently developing the commercial transportation acquisition strategy. NASA wants a full and open competition and looks forward to commercial crew transportation proposals.

13. What does NASA estimate would be the costs and schedule for development and subsequent operation of an Ares 1-based astronaut transport to low Earth orbit? In answering this, NASA should consider upper stage and crew module options that would cost less than those currently planned in the Constellation program, but should retain the current level 1 requirement for the number of astronauts to be delivered to the ISS and returned from orbit.

Answer: NASA has developed cost estimates for the Ares I crew launch vehicle as part of the Constellation Program. NASA has not initiated an assessment of options that would cost less than the current Constellation Program; therefore, at this time, NASA cannot provide information on this topic without extensive study.

14. What are the steps to human-rate a launch vehicle, how long is the process, and what are the projected costs to the government for human-rating a new commercially provided launch vehicle?

Answer: The steps to human-rate a launch vehicle that is built by, and/or purchased and operated by NASA are as follows: The initial step is to define the requirements to be applied to the launch vehicle. These requirements include application of the NASA Directives and Standards applied to all space vehicles as well as the application of the NASA Human-Rating requirements defined within NASA Procedural Requirements 8705.2B, Human-Rating Requirements for Space Systems. The program then implements that requirements set. The program's design and the processes used to obtain that design are evaluated by the three NASA Technical Authorities: the Chief Engineer, the Chief Safety and Mission Assurance, and the Chief Health and Medical Officer. At key milestones during the design process (System Requirements Review, System Design Review, Preliminary Design Review, Critical Design Review, and Operational Readiness Review), the design is subjected to formal review determining progress toward meeting the Human-Rating requirements. As part of these key milestones, the program develops the Human-Rating Certification Package (HRCP), a compilation of pertinent plans and documents that indicates how the program has implemented the human-rating requirements, how well the design accommodates human needs, how hazards are controlled and the safety risk associated with human spaceflight is managed, and how to the maximum extent practicable the system provides the capability to safely recover the crew from hazardous situations. These evaluations result in the three technical authorities and the Director, Johnson Space Center (JSC) (representing the crew), endorsing the updated HRCP, followed by endorsement by the programmatic elements (Associate Administrator for Exploration Systems and Associate Administrator for Space Operations). When the vehicle design, construction, and test are complete, and prior to the Flight Readiness Review, the program will prepare and submit a certification request to the three Technical Authorities, the Director, JSC, the Associate Administrator for Exploration Systems, the Associate Administrator for Space Operations and upon receipt of concurrences from those offices, the certification will be presented to the NASA Associate Administrator to provide the Human-Rating Certification. The length of the process is dependent upon the complexity of the design, and how the program schedules the major milestones based on the Agency budget allocations and approvals.

The Human-Rating Certification process was established to apply specifically to the development and operation of crewed space systems developed by NASA and used to conduct NASA human spaceflight missions. NASA is still deliberating on the approach to be used to obtain a new commercial launch vehicle. NASA will need to determine what specific process will need to be applied to determine if the vehicle is safe for flight. The length of this process and the cost of the process will be dependent up the type of acquisition process and agreements used to procure the launch vehicle.

Cooperation with China

15. Throughout much of the Cold War, NASA and the Soviet Union maintained cooperation in human spaceflight, particularly in astronaut health; what is the state of cooperation with China in human spaceflight, and what are its prospects?

Answer: Although the proposal to initiate a dialogue on human spaceflight was mentioned in President Obama's Joint statement with President Hu Jintao in November 2009, to date, NASA has not had any human spaceflight-related discussions with the Chinese.

<u>**Constellation Program Costs – Continuation and Cancellation**</u>

16. If NASA were to request a budget to continue the Constellation program while maintaining proposed spaceflight technology, aeronautics, and science investment levels, how much more money would have to be added to the budget each year above the projected run-out of the President's budget request?

Answer: In order to continue testing of Ares and development of Orion next year, NASA would need to utilize most of, or portions of, the existing Constellation elements (mission control, launch complex, ground processing facilities, program integration functions, etc.) in addition to having the funds required for Ares and Orion project continuation. For example, the other project elements would be needed in order to have a launch pad and processing facilities, integration of the vehicle, launch control center, and the ability to fit the systems together and work together.

The estimate for continuing this effort to support development of Orion and continued testing of Ares I would be approximately $3.5B in FY 2011 and would be required on top of the President's FY 2011 budget request for NASA's Exploration Systems Mission Directorate. The $3.5B assumes that the funding identified for termination and closeout of Constellation activities ($1.9B) in the FY 2011 budget request would instead be applied to the Constellation Program. In sum, the Constellation Program would need approximately $5.4B in FY 2011 for continuation of aforementioned program activities. If NASA were to continue development of Ares I and Orion, the year-to-year rate would be approximate to the total of $5.4B per year.

17. Going forward, could NASA land astronauts on the moon and return them safely to Earth by the end of the decade, and if so, what would be the additional budget requirement?

Answer: For the Augustine review in the summer of 2009, NASA estimated that the Constellation Program of Record, using Orion, Ares I, Altair, Ares V, and supporting elements, could deliver a crewed lunar mission by 2020, for $109B since the inception of the Constellation Program. Of this $109B since inception, $100.2B would be required in FY 2010 and out (the same time period as the Augustine estimates), and $96.7B would be required in FY 2011 and out. If the $1.9B of Constellation transition funding in the President's FY 2011 budget were applied to continue the Program of Record, approximately $95B of additional funding would be required in FY 2011 and beyond. However, achieving a crewed lunar mission by 2020 for this funding assumes that authority to proceed with lunar development occurs early in FY 2011, and sufficient funding is available in the early years of lunar development.

18. How much has been invested in the Constellation program to date?

Answer: As of April 12, 2010, from inception through March 2010, NASA has spent $10.0B on Constellation. Of that, $3.9B is on Ares I, and $4.1B is on Orion.

19. What are the cost and schedule estimates NASA has used in deciding to cancel the Constellation Program and in supporting the Augustine Committee review, and what are the bases of these estimates?

Answer: NASA provided technical and cost information during the FY 2011 budget formulation process, to help the Administration develop the President's budget. However, that information is part of internal Administration budget-formulation discussions and thus cannot be provided for the record. With regard to the Augustine Committee, NASA was able to provide cost, schedule and other technical data about the Constellation Program's status to the Augustine Committee. Much of this information is available at: http://www.nasa.gov/offices/hsf/related_documents/index.html

20. Going forward, what does NASA estimate will be the cost and development schedule for a new heavy lift launch vehicle, and what is the cost target for operation of such a vehicle, both annual base cost and incremental cost for each launch?

Answer: During his visit to KSC, the President specifically recognized the need for a heavy lift launch capability to carry humans beyond LEO by requiring a decision on a vehicle design no later than 2015. Such a decision would include setting performance goals, identifying lift capability and selecting the general vehicle design – work that will ultimately lay the path for launching a spacecraft for crewed missions into deep space.

The FY 2011 budget request includes funds for NASA to conduct the important R&D and analysis necessary to make an informed decision on a heavy-lift vehicle no later than 2015. A primary focus of this effort will be to conduct research and development on a U.S. first-stage hydrocarbon engine for potential use in heavy lift and other launch systems, as well as basic research in areas such as new propellants, advanced propulsion materials manufacturing techniques, combustion processes, propellant storage and control, and engine health monitoring. Additionally, NASA will initiate development and testing of in-space engines. Areas of focus could include a liquid oxygen/methane engine and lower-cost liquid oxygen/liquid hydrogen engines. This work will build on NASA's recent R&D experience in this area, and the test articles will be viewed as a potential prototype for a subsequent operational engine that would be re-startable and capable of high acceleration and reliability. These technologies will increase our heavy-lift and other space propulsion capabilities and is intended to significantly lower costs – with the clear goal of taking us farther and faster into space consistent with safety and mission success criteria. In support of this initiative, NASA will explore cooperative efforts with the Department of Defense and also develop a competitive process for allocating a small portion of these funds to universities and other non-governmental organizations. This research effort along with many of our new technology initiatives will be coordinated with the broader Agency technology initiative led by NASA's new Chief Technologist.

On May 3, 2010, NASA issued a Request for Information (RFI) seeking general information regarding potential launch or space transportation architectures (expendable, reusable, or a hybrid system) that could be utilized by multiple customers (e.g., NASA, commercial and other Government agencies). The RFI solicits information regarding propulsion system characteristics; technology challenges for propulsion systems; as well as innovative methods to manage a heavy-lift development program to include effective and affordable business practices. The RFI is open to the broad space community, including commercial, other Government agencies and academia. Information obtained from the RFI will be used for planning and acquisition-strategy development for current heavy-lift planning activities, funded in the FY 2010 Consolidated Appropriations Act (P.L. 111-117). Related to the RFI, on May 19, 2010, NASA posted a draft Broad Area Announcement (BAA). This draft BAA is soliciting proposals for a Heavy Lift and Propulsion Technology Trade study and seeks industry input on technical solutions in support of heavy lift system concepts studies. This draft BAA requests offerors to expand upon the previous NASA technical assessments and a final BAA solicitation will incorporate information obtained via the RFI as well as inputs from the upcoming Exploration workshop. These concept studies will include architecture assessments of a variety of potential heavy lift launch vehicles and in-space vehicle architectures employing various propulsion combinations and how they can be deployed to meet multiple mission objectives. Please note, the BAA is addressing FY 2010 planned activities which may also contribute to future plans and activities.

With regard to a specific cost estimate for heavy-lift, it is difficult to provide an accurate estimate given that this estimate would depend on type of vehicle chosen and its capabilities, among many other things. Such an estimate also would depend greatly on the phasing of funds available. However, NASA believes that cost savings could be realized by developing a heavy-lift vehicle that could be used by multiple users (EELV, commercial, other Government agencies.) As such, multiple users of the same vehicle would likely lower the overall lifecycle cost through higher production rates.

With regard to the $30-50B figure cited by NASA's Chief Financial Officer, NASA would like to clarify that those numbers are most closely related to the Ares V project and are rough cost estimates, based on varying assumptions. Based on preliminary Agency estimates, NASA anticipates that the Ares V project costs would be $27B – similar to the $30B ballpark figure cited at hearing. The $50B estimate cited is comparable to Ares V costs, including development and early production through 2025 -- again, if Ares I were cancelled. However, none of the aforementioned estimates include any of the any of the supporting elements required for launch, such as ground facilities, mission control, and program integration, or any payload. Those costs would be additional. (Note: Ares I and V share substantial development and fixed costs such as shared hardware, which must be considered in any estimate for one vehicle without the other. Therefore, if Ares I were continued, Ares V project costs through 2020, including development and early production would be around $16.5B.

21. If Constellation is cancelled as proposed, what components and technologies will remain useful to the restructured program of human spaceflight, and what is the amount that has been invested in each?

Answer: Following the release of the FY 2011 budget request, NASA established six study teams within ESMD to ensure we understand the steps (and the implications of those steps) that would need to be taken for an orderly transition of the Constellation Program and to plan for the implementation of the new Exploration program. The work undertaken by these teams is a necessary part of that planning. One team, the Constellation Transition team, has initiated a broad survey of current workforce, contracts, facilities, property, security, knowledge capture, information technology, and other Government agency interface issues to determine what infrastructure and hardware could be used by the new programs and projects.

Despite the early nature of these planning efforts, NASA is optimistic that there will be many capabilities developed by the Constellation Program that will feed forward into the new programs. For example, options using the Orion capsule are currently being pursued for autonomous rendezvous and docking; and many of the capabilities we are pursuing at a low level through our Exploration Technology Development Program are directly applicable to the new programs. Other important areas that will enable further advancement in the new initiative areas are: advanced robotics, propulsion development and test, friction stir welding, autonomous landing and hazard avoidance, and entry, descent, and landing technologies.

Additionally, on April 15, 2010, President Obama laid out the goals and strategies for his new vision for NASA. In doing so, he directed NASA to build on the good work already completed on the Orion crew capsule and focus the effort to provide a simpler and more efficient design that would provide crew emergency escape from the ISS and serve as part of the technical foundation for advanced spacecraft to be used in future deep space missions. NASA plans to be able to launch this vehicle within the next few years, creating an American crew escape capability that will increase the safety of our crews on the Space Station, reduce our dependence on foreign providers, and simplify requirements for other commercial crew providers. This approach also will preserve a number of critical high-tech industry jobs in key disciplines needed for our future deep space exploration program.

As noted earlier, given that the FY 2011 budget request is still pending with Congress, NASA has not yet made any final decisions with regard to what capabilities will and will not transfer to the new programs. Therefore, it would be premature for NASA to provide estimates about how much the Agency has already invested in these technologies.

22. If Constellation is cancelled as proposed, what amount of the investment through FY2010 will have been wasted?

Answer: As noted in the response to question 21, NASA is optimistic that there will be many capabilities developed by the Constellation Program that will feed forward into the new programs.

Industrial Base in Solid Rocketry

23. What is the current US industrial base for solid rockets capable of reaching low Earth orbit, what is the international capability for solid rockets and is the US the leader in this field? Was that National Security Council or the appropriate elements of the Department of Defense consulted on the implications of NASA's change in program for the industrial base in solid rockets?

Answer: NASA, the Department of Defense (DOD), the National Reconnaissance Office (NRO), and the White House work closely on the management of the National government space enterprise on a regular basis and they were fully informed on the results of the Review of the Human Spaceflight Plans Committee. Discussions are currently under way at all levels about ensuring we carefully consider and maintain the space industrial base.

While the FY 2011 budget request for NASA transitions away from Constellation, it also invests significant funding to develop technologies and infrastructure to enable human exploration both to low-Earth orbit and beyond. Although we do not yet know the specific human spaceflight technologies or programs and their potential impacts to the space industrial base, close consultation with the White House, DOD, and the NRO is underway. The NASA Administrator conducted a videoconference with Secretary Donley, General Kehler, and General Carlson just last month to discuss this topic, and plans to meet with them again early next month, as program decisions are made and we gain additional insight into the potential relevance to the space industrial base. We will continue to work closely with the White House, DOD, and the NRO as we move forward and, as an example, are already in discussions with DOD on our FY 2011 investment in range infrastructure and first-stage propulsion.

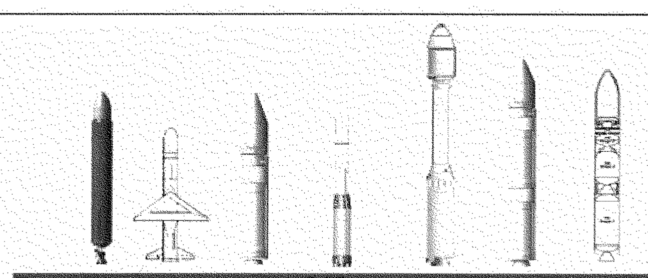
24. How do solid rockets compare with liquid rockets in thrust, weight to orbit, cost, and requirements affecting payload costs?

Answer: In general, U.S. small launch vehicles use solid rocket motors or LOX/RP (liquid oxygen and kerosene) engines for first stage propulsion. Medium and large class launch vehicles use liquid first stage (either LOX/RP or LOX/H2 [liquid oxygen and liquid hydrogen]) and augment vehicle performance using solid rocket motors as required to meet customer needs. The following figures provide U.S. launch fleet capabilities, based on public information.

Launch costs are not publically available, with the exception of SpaceX. Falcon 1 pricing is available at http://spacex.com/falcon1.php. Falcon 9 pricing is available at http://spacex.com/falcon9.php. Please contact United Launch Alliance (ULA) and Orbital Sciences Corp. for their latest pricing.

The following figures provide launch vehicle capabilities for representative small, medium, and Evolved Expendable Launch Vehicle (EELV) class launch vehicles.

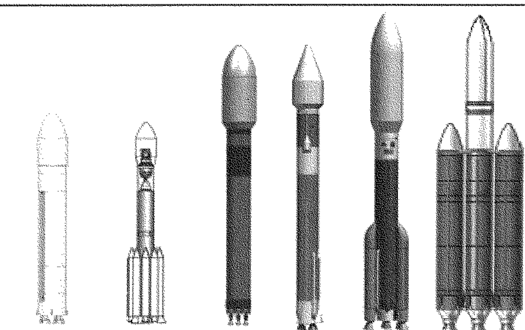
Small Launch Vehicle Performance Range (Kg)
Performance From Payload Planner's Guides or Company Estimates



Vehicle	Falcon 1	Pegasus XL	Athena I	Minotaur I	Taurus XL	Athena II	Minotaur IV
Payload to LEO kg	~500(a)	~450	~820	~580	~1450	~1150	~1735
First Stage engine	LOX/RP	Solid Rocket	Solid Rocket	Solid Rocket	Solid Rocket	Solid Rocket	Solid Rocket

(a): Falcon 1e concept with higher performance (~400kg) exists, but is in early development stage

Intermediate and Heavy Launch Vehicle Performance Range (Kg)
Performance From Payload Planner's Guides or Company Estimates



	Medium Class			EELV Class		
Vehicle	Taurus 2	Delta II	Falcon 9 Block 1 (b)	Atlas V 4XX	Atlas V 551	Delta IV + Heavy
Payload to LEO kg	1150 (a)	2450 to 5430	~10,450	9750 to 13,600	18500	9150 to 22,560
First Stage Engine	LOX/RP	LOX/RP	LOX/RP	LOX/RP	LOX/RP	LOX/H2

(a) Requires additional LV supplied upper stage for high energy missions
(b) Falcon 9 Block 2 upgrade planned (higher performing) – available ~4th qtr 2013

25. How do solid rockets compare with current technology liquid rockets for use as upper stages or candidate rockets for in-space launch?

Answer: Use of liquid engines or solid rocket motors are architectural trades each launch vehicle provider conducts to meet customer requirements. LOX/H2 engines provide the greatest upper stage performance. LOX/RP engines provide the next highest performance. Solid rockets provide the lowest in-space propulsion performance.

26. What is the safety record for solid rocket strap-ons compared to rockets that are purely in-line with each stage stacked above the others?

Answer: NASA's Exploration Systems Architecture Study (ESAS) did a detailed evaluation of the history of strap-ons and on-lines in order to estimate the probability of Loss of Crew (LOC) and Loss of Mission (LOM) per launch for ascent of a crewed launch vehicle. These are believed to be the most relevant numbers for comparison. Values determined were:

Human-Rated Atlas V (Strap-on)	LOC 1 in 957	LOM 1 in 149
Human Rated Delta IV (Strap-on)	LOC 1 in 1100	LOM 1 in 172
4 Segment RSRB with 1 SSME (In-line)	LOC 1 in 2021	LOM 1 in 460
5 Segment RSRB with 1 J-2S (In-line)	LOC 1 in 1918	LOM 1 in 433
5 Segment RSRB with 4 LR-85 (in-line)	LOC 1 in 1429	LOM 1 in 182

As identified above, the in-line design was determined to be generally more reliable and safer than the strap-on design. (Reference ESAS Final Report, NASA-TIM-2005-214062, November 2005, Chapter 6, Figure 6-95).

Robotic Exploration

27. The budget request envisions robotic missions within space exploration; what are the candidate destinations and mission goals for these missions and what is a possible schedule for these missions?

Answer: Under the FY 2011 budget proposal, one of the key contributors to a robust exploration program will be the acquisition of critical knowledge gained through the pursuit of exploration precursor robotic missions. Led by ESMD, this effort will send precursor robotic missions to candidate destinations that will pave the way for later human exploration of the Moon, Mars and its moons, and nearby asteroids.

Like the highly successful Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (LCROSS) missions that captured the world's attention last fall, future exploration precursor missions will scout locations, gather key knowledge and demonstrate technologies to identify the most compelling and accessible places to explore with humans and validate potential approaches to get them there and back safely. These missions will provide vital information—from soil chemistry to radiation dose levels to landing site scouting to resource identification—necessary to plan, design and operate future human missions. These missions will help us determine the next step for crews beyond LEO, answering such questions as: Is a particular asteroid a viable target for crewed mission? Do the resources at the lunar poles have the potential for crew utilization? Is Mars dust toxic?

NASA plans to begin funding at least two dedicated precursor missions in FY 2011, and to identify potential future missions to begin in FY 2012 and/or FY 2013. Dedicated precursor exploration missions are planned to remain below $800 million in total cost, and many will be considerably less expensive.

Additionally, a new portfolio of explorer scouts will execute small, rapid turn-around, highly competitive missions to exploration destinations. Generally budgeted at between $100-200 million lifecycle cost, these missions will allow NASA to test new and innovative ways of doing robotic exploration of destinations of interest to future human exploration. Selected projects may provide multiple small scouting spacecraft to investigate multiple possible landing sites, or provide means of rapid-prototyping new spacecraft approaches.

Space Shuttle

28. What schedule issues exist with respect to the remaining Space Shuttle manifest, and in particular, what is the current launch readiness date of the DOE AMS payload?

Answer: The President's FY 2011 budget request for NASA includes $600M to continue to operate the Space Shuttle Program into FY 2011 to ensure that the three remaining manifested missions (including STS-132, launched on May 14, 2010) can be flown safely to complete the outfitting of the ISS. It is important that these missions be flown in order to ensure ISS operations and utilization after the retirement of the Shuttle fleet. In addition to the provision of critical spares to the ISS, the AMS experiment is to be flown to the Station on STS-134 currently scheduled for November 2010. This experiment will conduct important particle physics observations, using a unique instrument developed by investigators from 60 countries. This experiment has been in development for 11 years involving significant investment for high-energy particle physicists from around the world. This experiment needs the continuous exposure to space afforded only by the ISS.

29. If AMS launch readiness were to cause delay in the final Shuttle mission into FY11, what is the scientific justification for NASA incurring $600 million in additional costs, and how long an extension of the Shuttle program is justified – 4 months, 6 months, a year?

Answer: The President's FY 2011 budget request for NASA includes $600M to continue to operate the Space Shuttle Program into FY 2011 to ensure that the remaining three manifested missions (including STS-132, launched on May 14, 2010) can be flown safely to complete the outfitting of the ISS. It is important that these missions be flown in order to ensure ISS operations and utilization after the retirement of the Shuttle fleet. In addition to the provision of critical spares to the ISS, the AMS experiment is to be flown to the Station on STS-134. This experiment will conduct important particle physics observations, using the unique environment of space to advance knowledge of the universe and lead to the understanding of the universe's origin by searching for antimatter, dark matter and measuring cosmic rays.

30. What is NASA's projected cost for extension of Shuttle capability with a flight rate of two launches per year, and what launch schedule would NASA be able to achieve?

Answer: NASA fully supports the President's FY 2011 budget request, which reaffirms our current plan of retiring the Space Shuttle in 2010. The most recent full cost estimate to extend the Shuttle beyond 2010 is approximately $2.0 - $2.5 billion per year. If NASA were directed to extend the Shuttle, there would be time required to restart production on components such as external tanks. This time is estimated as two-three years depending upon the time required to rehire employees and the material available for restart. We could slow the flight rate of current missions and minimize the gap between flights. If we did not slow the current flight manifest beginning with STS-132, we would have a gap of 19-22 months. Also, the NASA Aerospace Safety Advisory Panel does not support extending the Shuttle significantly beyond its current manifest. The panel's Chair Vice Admiral Joseph W. Dyer has said it is "especially concerned over any kind of 'serial extension' where a few flights at a time might be added."

Launch Services

31. To what extent and in what ways would the program supported by the FY11 budget request improve US competitiveness in the launch services market?

Answer: The President's FY 2011 budget request for NASA supports U.S. competitiveness in the launch services market by appropriately supporting emerging launch service capabilities through Space Act Agreements (SAAs), including continued investment in the Commercial Orbital Transportation Services (COTS) project. Specifically, the budget provides nearly $6 billion to support development of commercial crew services by new and existing launch service providers. In addition, the proposed extension of ISS operations beyond 2015 provides a continued market for cargo delivery that has begun under the Commercial Resupply Services (CRS) contracts. The FY 2011 budget request also includes funding for purchase of launch services for NASA science missions. The budget also funds propulsion research and development that may end up improving future commercial launch vehicles. NASA also supports the launch services market by acquiring launch services in a range of performance levels from a variety of service providers to meet NASA's needs.

Heavy Lift Launch Vehicle Development

32. Does NASA intend to focus its heavy lift launch vehicle development on liquid rockets, liquid rockets with solid strap-ons, or solid rockets, and why?

Answer: The FY 2011 budget request funds NASA to develop affordable engines for use by multiple customers (NASA, other government agencies, and commercial) with associated technologies to support those engine development activities. While this plan requests the development necessary propulsion systems and enabling technologies for a future heavy lift launch vehicle, it does not directly provide for such a vehicle. The engine is typically the critical path item in any launch vehicle development therefore this new plan will allow for NASA to start development early on the most challenging part of a launch vehicle development to reduce risk.

More specifically, the FY 2011 budget request introduces a new Heavy-Lift Research and Development (R&D) Program that will focus on developing game-changing technologies to help reduce cost overall by improving our space launch propulsion technologies. This effort will include development of a U.S. first-stage hydrocarbon engine for potential use in future heavy lift (and other) launch systems, as well as basic research in areas such as new propellants, advanced propulsion materials manufacturing techniques, combustion processes, and engine health monitoring. Additionally, NASA will initiate development and in-space testing of in-space engines. Areas of focus could include a liquid oxygen/methane engine and also low-cost liquid oxygen/liquid hydrogen engines. This work will build from NASA's recent R&D experience in this area, and the test articles will be viewed as a potential prototype for a subsequent operational engine that would be restartable and capable of high acceleration and reliability. These technologies will increase our heavy-lift and other space propulsion capabilities and significantly lower operations costs – with the clear goal of taking us farther and faster into space consistent with safety and mission success criteria. In support of this initiative, NASA will explore cooperative efforts with the Department of Defense and also develop a competitive process for allocating a small portion of these funds to universities and other non-governmental organizations. This research effort along with many of our new technology initiatives will be coordinated with the broader Agency technology initiative led by NASA's new Chief Technologist.

In addition to investing in transformative heavy-lift technologies, the President has called on NASA to select a rocket design, no later than 2015, and then begin to build it. A decision no later than 2015 means that major work on building a new heavy-lift rocket will likely begin two years sooner than in the previous plan.

Following the release of the FY 2011 budget request, NASA established six study teams within the Exploration Systems Mission Directorate to ensure we understand the steps (and the implications of those steps) that would need to be taken for an orderly transition of the Constellation Program and to plan for the implementation of the new Exploration program. The work undertaken by these teams is a necessary part of that planning. This is only an evaluation of plans, and no termination action has been directed or taken. The data assembled by the study teams will equip NASA with vital and substantive information that we will need once the new fiscal year begins and once an FY 2011 budget has been approved by Congress and NASA embarks on the approved FY 2011 budget request. For example, the Heavy Lift and Propulsion Technology is formulating plans for a program that will investigate a broad scope of R&D activities to support next-generation space launch propulsion technologies. This includes foundational propulsion research and demonstrations of first stage and in-space engines.

It is expected that teams will complete a majority of their work by the end of the third quarter of FY 2010. As that effort is completed over the next several months, NASA will share our findings with Congress with regard to our planned next steps.

33. Does NASA require a heavy lift launch vehicle to be human rated and if so, why?

Answer: As of this date, no decision has been made as to whether the heavy-lift vehicle system will be used to transport U.S. astronauts.

NASA Facilities

34. Across the agency, what NASA property is being leased out, what property is projected to be leased out, what lease proceeds are projected, and how are these proceeds managed?

Answer: At the end of FY 2009, ARC had 48 Enhanced Use Lease (EUL) agreements, with industry and academic partners. Numerous leases have been approved and entered into for tenants in the NASA Research Park (NRP) at ARC. The NRP is intended to be a high-technology campus in the heart of Silicon Valley at ARC

At the end of FY 2009, KSC had 12 EUL agreements with industry (wireless cell towers) news media (communication support), Florida Power & Light and Space Florida (for the purpose of developing a technology and commerce park, to be known as Exploration Park at Kennedy Space Center).

Ames Research Center (ARC):

ARC has two major EUL proposals it is considering for implementation in 2010. In addition to these, ARC has a number of small EULs with industry partners.

Airship Earth (AE) EUL: Airship Earth is a focused, mission-driven, non-profit organization in the NRP with two purposes: 1) lead the development of Archangel, a Disaster Response and Risk Reduction Communications Network, to enhance the capacity of nations, states, communities, nongovernmental organizations, militaries and other humanitarian emergency organizations to more effectively respond to and mitigate short-term and long-term natural and manmade disasters such as wildfires, earthquakes, tsunamis and pandemics; and, 2) reduce global warming and poverty by creating market-based mechanisms in which community-based forest protection and restoration projects remove greenhouse gases from the atmosphere, deliver ecological co-benefits and new financial flows to the communities involved with forest protection and restoration. AE has future plans for expanding their footprint at NRP, which include adaptive re-use of a historic building into a Disaster Response Communication Facility.

Carnegie Mellon Expansion: Carnegie Mellon University is a private research university with a distinctive mix of world-renowned programs in engineering, computer science, robotics, business, public policy, fine arts and the humanities. In 2002, Carnegie Mellon established its Silicon Valley campus at Moffett Field in Mountain View, California by renovating Historic Building 23 at ARC-Moffet Air Field. This lease was entered into under the National Historic Preservation Act and is not an EUL. However the potential expansion of Carnegie Mellon's presence is planned as an EUL. Carnegie Mellon will expand the reach of its outstanding professional programs and perform innovative research that connects it to local, national, and global high-tech companies. In FY2010, Carnegie Mellon is planning to expand its West Coast Campus by leasing additional office space in NRP's Bldg. 19 for a Center for Collaboration Science and Applications, Disaster Management Initiative and Carnegie Mellon Innovations Laboratory (CMIL).

Kennedy Space Center (KSC):

KSC continues to review the potential for out-grant of portions of the underutilized land surrounding (as a buffer zone) and in the Center. These out-grants may be under EUL or may be under other existing NASA authority. These include leases with communications service providers and media and media support organizations. The leases are small-area leases of land or structures to support commercially-provided telecommunications services such as cell phone towers/antennas. This follows a number of existing leases for communications support that expand services at KSC as well as in the surrounding area. The leases with media and media support organizations are anticipated to be new leases to replace expired leases or support new users engaged in media activities at the KSC Press Site, including news media organizations and related support.

Potential EUL Agreements at Other NASA Centers:

The expansion of NASA EUL authorities will have a positive benefit for all NASA Centers. Beyond the activities of ARC and KSC reported above, several other NASA Centers have begun investigating the use of EUL to improve the management of the real property under their control.

Glenn Research Center (GRC) (Lewis Field and Plum Brook Station):

GRC is reviewing the potential for three EULs:

- lease of the Plum Brook Station Rye Beach raw water system to the Erie County Water Authority to improve the county's water supply and to support further development in the county;
- lease of buffer zone land at Plum Brook Station for possible development including development as a wind farm in support of the Administration's energy and environmental objectives; and,
- Lease of North Area at Lewis Field for potential development.

Please see the table below for a listing of projected lease expenses and revenues for FY 2010 from Ames Research Center and Kennedy Space Center

FY2010 EUL Expenses and Revenues ($K)	ARC	KSC	Total
Base Rent	$ 5,196.7	35.7	5,232.4
Institutional Support Income	1,803.7	21.0	1,824.7
Total Rent Income	**$ 7,000.4**	**56.7**	**7,057.1**
Institutional Support Costs	$ (1,803.7)	(21.0)	(1,824.7)
Lease Management and Administration	(700.0)	-	(700.0)
Tenant Building Maintenance and Repair	(310.5)	-	(310.5)
Total Cost Associated with Leases	**$ (2,814.2)**	**(21.0)**	**(2,835.2)**
Net Revenue from Lease Activity (Total Rent less Total Cost)	**$ 4,186.2**	**35.7**	**4,221.9**
Beginning Balance, Capital Asset Account, as of 10/1/2009	**1,531.3**	**49.8**	**1,581.1**
Total Available for Obligation in FY 2010	**$ 5,717.5**	**$ 85.5**	**$ 5,803.0**
- Various Historic Building or Safety Renovation Projects	(3,381.7)		(3,381.7)
- FY09 Projects not initiated by 1 October	(994.8)		(994.8)
- Capital Revitalization & Property Improvements		(49.1)	(49.1)
Capital Asset Account Expenditures	**(4,376.5)**	**(49.1)**	**(4,425.6)**
Capital Asset Account Ending Balance	**1,341.0**	**36.4**	**1,377.4**
Additional Reimbursable Demand Services Requested by Leasees (including overhead)	$ 1,814.1		1,814.1
Cost to Fulfill Reimbursable Demand Services (including overhead)	(1,814.1)		(1,814.1)
Net activity due to Reimbursable Demand Services	**$ -**	**-**	**-**
In Kind Activity	**$ 425.0**	**-**	**425.0**

Definitions

Base Rent - Revenue collected from tenant for rent of land or buildings

Institutional Support Costs - Cost for institutional shared services such as fire, security, first responder, communications, common grounds, road, and infrastructure maintenance, and routine administrative support and management oversight (i.e., environmental).

Total Rental Income - Total gross proceeds from EUL activities for expenses due to renting NASA property

In-Kind - Consideration accepted in lieu of rent payment. (Only applies to selected leases signed prior to Jan 1, 2009)

Reimbursable Demand Services - Services such as janitorial, communications, and maintenance that solely benefit the tenant and provided for their convenience. There is no net income received by NASA , as these payments may only cover the costs of NASA and its vendors providing these services.

Overhead - General and administrative costs associated with management of the specified demand services.

35. How does NASA use enhanced use leases and how are proceeds spent?

Answer: NASA utilizes EUL as a tool to support appropriate and responsible management of its real property. Since there are facilities that are currently underutilized but are unique assets to the Agency, NASA considers EUL a tool to aid in the preservation of these non-excess assets rather than allowing them to fall into disrepair. Other assets that are underutilized may be considered for abandonment and eventual demolition. Assets that have historic value may be leased under EUL rather than being considered for abandonment and eventual demolition. NASA is currently pursuing interest in using the buffer zones in and around NASA facilities for the generation of renewable energy.

Revenues received may be used (1) to cover the full costs to the Center in connection with the lease; and, (2) available for maintenance, capital revitalization, and improvements of the real property assets and related personal property. This includes the revitalization, repair and replacement of collateral equipment.

EUL funds may be utilized to cover full-cost of lease management and administration charges, which may include, but not limited to , personnel (but not civil service) and other expenses incurred by the Center for administrative, legal, and other services for EUL support activities (e.g., contract support, contract management, financial management). Full cost to NASA in connection with leases is fully defined in NPR 9090.1. Briefly, these costs include those that reflect the indirect cost, general use of facilities services (e.g., shared charge for security services, procurement activities) and building maintenance (including both routine and major building repairs. Additionally the costs may include personnel cost (but not civil service) and other expenses incurred by the Center for administrative, legal and other services for lease support activities. The costs to NASA may also include costs for site preparation specific to the leased property such as basic upgrades so that a property can be considered viable for leasing and building modifications or customizations in order to accommodate EUL leases. However these site preparation costs are to be billed to the tenant in addition to regular recurring lease payments.

Under NASA's EUL authority, the net proceeds are deposited into an Agency capital asset account managed by Headquarters. Funds are then distributed from that account. Sixty-five percent of the revenue will then be distributed back to the Center generating the proceeds, to be used to fund the HQ approved facilities project list. Projects will be prioritized and approved based on Agency-approved discriminating factors, which ensure support of NASA's primary missions, reduce NASA operating costs supporting those missions, and ensure a safe, reliable and adequate environment for NASA workers. The facilities project list to be funded from the Capital Assets Account will be submitted to Congress, as part of the budget development process discussed above, which will provide visibility into these projects as part of the NASA budget process. Thirty-five percent of the revenue is retained in the Capital Asset Account and is available for maintenance and capital improvements at the direction of the Administrator. These funds will be distributed to NASA Centers based upon projects approved and prioritized with preference given to construction and repair projects that reduce utility costs, increase NASA's use of renewable and alternative energy sources, and projects that facilitate reduction of NASA's future operating costs. This list of projects will also be submitted to Congress as described above.

36. Under what authority are proceeds from enhanced use leases spent?

Answer: In 2003, Congress enacted Public Law 108-7, which granted authority to the Administrator of NASA to enter into a demonstration project for Enhanced-Use Leases on property at two NASA Centers. Ames Research Center in California and the Kennedy Space Center in Florida were selected by NASA as the two demonstration Centers.

In 2007 and again in 2008, Congress amended NASA's EUL authority. The amendments in 2007 allowed NASA to enter into enhanced use leases at all Centers. The amendments in 2008 clarified how the funds should be expended and established percentages of the revenue that were allocated to the Centers generating the proceeds and that percentage available for use at an Agency level.

Under the current authority, all NASA Centers may enter into EUL agreements. The authority states:

- Agreements may only be for cash consideration, at fair market value determined by the Administrator,
- No in-kind consideration is allowed for leases under the expanded authority; leases executed before December 31, 2008 may continue to include in-kind consideration.
- The amounts of cash consideration received may be used to cover the full costs to NASA in connection with the lease;

The FY 2010 Consolidated Appropriations Act (P.L. 111-117) changed the Agency's enhanced use lease authority. While P.L. 111-117 did not provide specific language amending 42 U.S.C. 2459j, relevant language of the Act must be incorporated into the existing program.

Based on the above requirements, NASA has incorporated the following in the Agency EUL Desk Guide:

Proceeds from EULs shall be deposited into the Construction and Environmental Compliance and Remediation (CECR) account and shall be available for a period of five years for projects subject to approval and provided in annual appropriations Acts:

Annual budget requests shall include an annual estimate of gross receipts and collections and proposed use of all funds collected under EUL authority; and proceeds from EUL funds from the CECR for FY 2010 obligation cannot exceed $6,226,000.

- Of any amounts of cash consideration received that are not utilized to cover the full costs of the lease to NASA;
- 35 percent of funds collected under EUL authority in excess of the full costs of the EUL shall be deposited in the CECR Account and shall be available for maintenance, capital revitalization, and improvements of the real property assets and related personal property under the jurisdiction of the Administrator, and shall remain available for 5 years to the extent provided in annual appropriations Acts; and
- the remaining 65 percent shall be deposited in the CECR account and shall be available to the respective center or facility of the Administration engaged in the lease of non-excess real property, and shall remain available for 5 years to the extent provided in annual appropriations Acts for maintenance, capital revitalization, and improvements of the real property assets and related personal property at the respective Center or facility subject to the concurrence of the Administrator.
- Funds may be used on any real property at the Centers including collateral equipment, and does not have to be spent on facilities or infrastructure that are leased out under EUL; and,
- Funds may not be utilized for daily operations costs.

37. Across the agency, to what extent do NASA facilities have excess site footprints and excess facilities that need demolition or are appropriate for use by others?

Answer: NASA's facility inventory identifies approximately 190 abandoned facilities. Abandoned facilities make up three to four percent of NASA's total facilities. These facilities will be scheduled for demolition as resources are available within NASA's demolition program. NASA prioritizes demolition of these facilities based on annual cost to maintain the facilities in a safe status and potential liability associated with keeping the facility. NASA anticipates that it will continue to identify facilities for demolition for the foreseeable future as it works to reduce un-needed infrastructure and revitalize critical infrastructure.

NASA has 97 facilities in mothball condition. These are facilities that are currently not utilized by NASA but support capabilities that NASA believes may be required in the future by either NASA or by others. Many of these facilities are "long cycle" research facilities that are required for testing at certain stages in a development program but are not required for routine validation or quality assurance testing. NASA periodically evaluates mothballed facilities to determine if they may be required in the future. If NASA determines that a facility no longer supports a potential future capability, the facility is moved from mothball status to abandoned condition and is scheduled for demolition as resources become available.

NASA has out-granted 87 facilities to other users. These facilities are used full-time by others to support other Federal missions or to support national aerospace initiatives.

Finally, NASA partners with other Federal agencies and private firms to provide the capabilities of some NASA research facilities in support of aerospace research and development. Examples of these partnerships are the B2 rocket propulsion test stand at Stennis Space Center and several of NASA's wind tunnels. These partnerships make these national assets available to support advances in engineering and science. NASA participates with several national test alliances to make these capabilities available to other users.

38. Across the agency, what is the status of deferred maintenance, demolition, and toxic site clean-up?

Answer:

Deferred Maintenance:

The FY 2009 facility assessment identified $2.55B in deferred maintenance for NASA's facilities. This is an increase of $90M over the FY 2008 assessment. Between 2005 and 2008, deferred maintenance grew at an average rate of 7.66 percent per year. Between 2008 and 2009 this growth was only 3.45 percent. This reduced growth was attributed to several factors, including the replacement of several older facilities, completion of post hurricane Katrina and Ike repairs, and NASA's active demolition program.

Demolition:

Between 2005 and the end of FY 2009, NASA demolished 381 facilities with a value of $260.9M. NASA estimates that this demolition allowed Centers to redirect approximately $4M of annual maintenance funding that was used to maintain unused facilities in a safe condition to critical facilities supporting NASA's current missions. NASA's current demolition plan identifies 81 demolition projects between FY 2010 and 2012. NASA's demolition plan for FY 2010 through FY 2012 focuses on reducing Space Shuttle retirement costs by demolishing facilities that will not be needed after the final Space Shuttle flight.

Evaluation of annual assessment and demolition data shows that demolition is an important part of NASA's efforts to reduce un-needed infrastructure, reduce NASA deferred maintenance, and redirect scarce maintenance funds into NASA's critical facilities. NASA identifies facilities for demolition as part of its annual budget formulation process (PPBE) and intends to maintain an ongoing demolition program for the foreseeable future.

Site Clean-up:

Federal and State environmental laws require cleanup of NASA sites to protect human health and the environment and restore land and natural resources for mission use. The cost of these actions is reported as an unfunded environmental liability on the Agency financial statement. At the end of FY 2009, NASA has indentified an unfunded environmental liability of $812M that covers actions to implement clean up all of NASA's toxic sites across the Agency and maintain cleanup remedies for 30 years. This represents a decrease of $130M from 2008 and is due to changing reporting policies and continued funding of cleanups under the Agency's Environmental Compliance and Restoration (ECR) Program.

In FY 2010, the NASA ECR Program provided funding of approximately $55M for investigations and cleanup actions. Cleanup actions include construction of treatment systems, removal of chemicals from soils/groundwater, and operation of groundwater treatment systems. Several projects are nearing milestones, such as the FY 2011 completion of the nuclear reactor decommissioning at Plum Brook Station, Ohio. Due to the nature of chemicals and complex site conditions, complete cleanup of groundwater may take from decades to over 100+ years.

39. What are NASA's requirements and plans to retire computer systems, software, and networks dating from the last century?

Answer: NASA has developed a comprehensive plan to retire, transition, or upgrade our computer systems, software, and networks with consideration for program lifecycle and mission/mission support dependencies. An example of this activity is the comprehensive planning of the Space Shuttle Programs (SSP) Information Technology (IT) systems and associated software, which will be transitioned, archived, or deleted. It is anticipated that calendar year 2011 will be the most active year for the SSP IT systems disposition, with completion currently planned for December 2012. To facilitate the disposition of these systems and assets, through a SSP Directive issued January 2010, an indexed repository of approximately 100 data elements that include hardware, software, applications, and IT Security planning is being established. The identification of assets is still underway and may be impacted due to the dynamic nature of the Constellation program and ability to repurpose assets. SSP is committed to the reuse and transition of assets and has increased efforts, to include staff support time, to facilitate reuse and transition to other non-SSP organizations. SSP is not seeking reimbursement for IT investments, but expects the receiving organization to assume maintenance and operating costs after transition. December 2012 represents the end of a multi-year process of viable dispositioning of IT investments, and any remaining systems will be assumed to be at the end of their lifecycle and dispositioned accordingly.

NASA is investing in upgrading aging and obsolete networks and their components across the Agency to include significant investment over the past two years in NASA's Wide Area Network backbone in support of mission and mission support requirements For FY 2011, NASA plans continued upgrades to networks at Glenn Research Center, Ames Research Center, Goddard Space Flight Center, Kennedy Space Center, Langley Research Center, Marshall Space Flight Center, and Stennis Space Center using a combination of Center funding and Strategic Institutional Investment funding. Once these upgrades are completed, Kennedy Space Center will be the only Center with significant network upgrade requirements remaining, mostly due to the miles of 1960 era air-core cabling traversing the Center. This cabling is being replaced in segments as funding becomes available. Complete replacement of air-core cable segments will take several years. NASA will ensure any new cable requirements align with the KSC facilities master plan and other required Center modifications to execute the Agency's mission.

NASA is in the process of retiring all applications currently using the SSP mainframe and porting the applications over to newer systems and technologies. The remaining SSP mainframe data will be archived upon its scheduled to retirement in 2012. As an example, the NASA Supply Management System currently running on the mainframe will be retired in FY 2011 after a new module is implemented under NASA's SAP Enterprise Application.

Supercomputing

40. How is NASA supporting the supercomputing requirements of its internal and funded external research and development activities, and are NASA's supercomputing resources enabling or constraining NASA R&D?

Answer: NASA supports the Agency's supercomputing requirements for its internal and funded external R&D activities via the High End Computing Capability (HECC) and Scientific Computing projects. HECC, located at Ames Research Center, supports all four Mission Directorates and their sponsored research and collaborative programs. Scientific Computing, located at Goddard Space Flight Center, mainly supports large-scale Earth science climate research projects. Both of the supercomputing facilities are fully subscribed in support of the Agency's R&D requirements and external partners. A multi-mission computing resource allocation panel is responsible for the allocation among the missions.

Two major supercomputing resource requirements come from (1) NASA's flight missions (both human and robotic) and (2) NASA's research programs in Earth and space sciences and aeronautics. Supercomputing requirements from flight mission developments are typically milestone driven and time-sensitive while research program requirements are typically not time-sensitive. NASA's strategy is to maintain a capable supercomputing resource baseline at HECC to support both flight missions and research programs while allowing the programs and projects to add additional budget resources for HECC to acquire surge capacity when necessary. This model allows NASA to maintain adequate supercomputing resources for time-sensitive requirements while maintaining the necessary capability for non time-sensitive research requirements when flight projects do not require the assets. NASA's research programs manage the supercomputing requirements considering the overall program balance, scientific progress, research breakthrough opportunities, and budget availability.

NASA's supercomputing resources have been instrumental in supporting the Agency's mission and vision and include R&D and modeling such as: Constellation program's vehicle design, Mars Science Laboratory mission's parachute design and analysis, the Fundamental Aeronautic Program's rotary wing development, Earth science's climate simulation and Earth observing satellite data processing, and Heliophysics' space weather simulation and data analysis. Responding to the challenge of climate and environmental change, the FY2011 budget request includes an increase of research funding in modeling, assessment, and the associated computational resources to expand NASA's contribution to nationally and internationally collaborative research activities such as the 2013 National Assessment by the U.S. Global Change Research Program (USGCRP) and the next mitigation and adaption assessment of the Intergovernmental Panel on Climate Change (IPCC).

Directors Discretionary Funding

41. How much funding is available to NASA center directors, including the director of JPL, for discretionary research and development funding, for what purposes is any funding being used, and what effect is the amount of funding provided having on the NASA enterprise?

Answer: NASA Centers and JPL fund small, select R&D activities at the discretion of the installation Director. This effort, known as Independent Research and Development, focuses on technology investments aligned with future NASA mission challenges. It is intended to demonstrate the feasibility of new technologies for future R&D areas. The selected activities typically are expected to have the potential for high-payoff breakthroughs, as measured by infusion or transition of the new technology into a program activity. The amount funded varies depending on Center mission and role, but averages approximately 0.3 percent of each installation's total programmatic and institutional budget. The FY 2011 estimate for these activities is $50M.

STEM Education

42. How will the Summer of Innovation program strengthen STEM education?

Answer: The Summer of Innovation (SOI) is one of several projects in NASA's Elementary and Secondary Education (ESE) Program. Investments in ESE focus on improving science, technology, engineering, and mathematics (STEM) teaching and learning in the K-12 classroom. NASA's STEM Student Opportunities focus on engaging and retaining students in STEM education programs to encourage pursuit of NASA's future engineering, scientific, and technical missions through flight opportunities, hands on research and engineering experiences, and increased knowledge of NASA science and technology content. NASA's STEM Teacher Development projects use the Agency's unique content and resources to provide pre-service and classroom teachers with learning experiences that build critical instructional STEM skills and enable teachers to better motivate students to achieve academic excellence and pursue STEM careers. The SOI project is a student-focused activity with emphasis on community involvement.

Each funded SOI project is required to have its own evaluator to assess the project. NASA Office of Education (OE) will also conduct a national level evaluation of SOI projects. The evaluation will be a three-year comparison of similar impacts across projects and measure the effectiveness of the different SOI strategies. Data will be drawn from existing OE surveys and data collection forms related to student STEM engagement, teacher STEM professional development, the development of partnerships, the use of NASA materials in the classroom, and teacher instruction. Project impacts will be assessed using existing data from State education data systems, which may include student Grade Point Average, scores on standardized assessments, student STEM course selection, grades in specific classes, etc. NASA will be able to determine which models have the greatest impact on STEM academic outcomes of students who have traditionally been underrepresented, underserved, and underperforming in STEM subjects. In addition to measuring impacts, the SOI national evaluation will include a thorough description of interventions and impacts.

43. How will the Summer of Innovation program contribute to the reform of STEM education and the broad inclusion of inquiry therein?

Answer: In 2008, Congress directed a review of the ESE program by the National Academies. The committee provided NASA with a series of findings and recommendations to improve the program and help strengthen STEM education in the United States. The SOI project is closely aligned with the four following recommendations:

- Recommendation 1: *"NASA should continue to engage in education activities at the K-12 level, designing its K-12 activities so that they capitalize on NASA's primary strengths and resources, which are found in the mission directorates. These strengths and resources are the Agency's scientific discoveries; its technology and aeronautical developments; its space exploration activities; the scientists, engineers, and other technical staff (both internal and external) who carry out NASA's work; and the unique excitement generated by space flight and space exploration."*
- Recommendation 6: *"NASA program and project planning and execution should make better and more consistent use of opportunities to involve education stakeholders, to partner with individuals and organizations that can provide expertise in education and to connect to the existing infrastructure for K-12 STEM education."*
- Recommendation 7: *"NASA's partnerships in education should be designed in light of the specific objectives of each project. NASA can play a lead role in projects intended to inspire and engage students and should use strategic partnerships to leverage the impact of such projects. For projects designed to affect schools, through work with students, teachers, or curriculum materials, NASA should work in partnerships with organizations that complement NASA's science and engineering expertise with education specific expertise and avenues of dissemination. All partnerships should begin during the early stages of project design."*
- Recommendation 19: *"NASA should plan the scale, design, and frequency of each project evaluation so that it aligns to the scale and goals of the project and to the nature of the decisions that need to be made."*

The 2010 SOI pilot program will be evaluated to produce knowledge about which types of interventions are more effective in improving student outcomes. The goal is to identify strategies that improve STEM academic performance in students who have traditionally been underrepresented, underserved, and who have underperformed in STEM subjects.

44. What effort will be devoted to continuing the innovative summer during the fall, winter and spring of regular schooling?

Answer: STEM learning communities will be established to sustain student interest and achievement. By fostering collaborations and partnerships, the STEM support community can ensure that teachers are better able to successfully teach STEM topics, and that students remain motivated to learn and achieve in STEM. The community will offer opportunities designed to keep summer participants (and other students, whenever possible) engaged. These activities may include but are not limited to supporting engineering design challenges, teacher workshops, community and family events, peer-to-peer mentoring, and/or involvement in special events and activities offered by NASA and its partners. Schools will be encouraged to participate in other NASA education projects, including the newly redesigned NASA Explorer Schools.

45. What role is NASA playing in Department of Education STEM education programs, and does this include participation in program implementation activities such as proposal evaluations, selection of grantees, performance reviews?

Answer: The OE has a positive and collaborative relationship with the leadership of the Department of Education (ED) resulting in an on-going exchange of ideas and identification of new opportunities for collaboration. OE looks forward to working with Secretary Duncan and his staff to further develop this association and promote President Obama's agendas for education, science and technology, and innovation.

- Dr. Michael Lach, ED Deputy Secretary and Special Advisor to the Secretary for Science has consulted with OE leadership on the development of a Cooperative Agreement Notice (CAN) for the SOI, defining strategic partners and planning to the NES model redesign and pilot, and other STEM programmatic topics at NASA. NASA plans to involve Dr. Lach in education "design team" activities.
- Dr. Lach is discussing a Federal STEM education strategy with NASA and other members of the National Science and Technology Committee (NSTC) Subcommittee on Education.
- NASA identified a need for action in attracting and retaining females in STEM fields. The White House Council of Women and Girls (WHC WG) has included this issue in its top four priorities for the Council. Former NASA Associate Administrator for Education (AA) Dr, Joyce Winterton and Steve Robinson, Special Advisor on STEM Education to Secretary Duncan (currently detailed to the Office of Science and Technology Policy), were co-panelists in a special meeting on STEM and issues impacting women and girls.
- Russlynn Ali, ED Assistant Secretary for Civil Rights also serves on the WHC WG and was a co-panelist with Dr. Winterton during a special event highlighting the history and achievements of Title IX. The need for female STEM role models was a key discussion topic at the event.
- Dr. Steve Robinson, Special Advisor on STEM Education to Secretary Duncan, was the keynote speaker at launch forum involving key education stakeholders.
- Dr. Robinson participated in a strategic discussion with other national leaders regarding the redesign of NASA's Explorer Schools (NES) project.
- Former ED Deputy Secretary Ray Simon and hundreds of educators participated in an STS-118 education conference and events marking the mission of Educator Astronaut Barbara Morgan.
- NASA and ED staff are routinely called on to serve as peer reviewers and panelists for federal STEM grant programs, including programs at

Department of Energy (Energy), National Atmospheric and Oceanic Administration (NOAA), and National Science Foundation (NSF). ED, Department of Defense, NOAA, NSF and other federal staff serve on similar NASA panels.
- NASA has provided professional development experiences for ED staff and education staff at other STEM agencies.

Beyond a growing leadership relationship, NASA and ED interact in two distinct ways.

The first relates to implementation of NASA-themed STEM education activities in cooperation with ED. NASA provides its rich STEM content, education materials, and unique resources (e.g. engineers and scientists, education technologies, flight platforms, astronauts) in support of ED initiatives.

- The SOI pilot is aligned to the goals of *Race to the Top*, *Educate to Innovate*, and *Investing in Innovation* initiatives led by ED and the White House.
- International Education Week activities usually include an International Space Station (ISS) downlink and education activities provided by NASA.
- The Teacher to Teacher Initiative at Johnson Space Center (JSC) inspires educators in teaching STEM disciplines.
- STS-118 and other special events with the space shuttle crews inspire students (crew and education activities).
- NASA provided speakers in support of the Math and Science Partnerships meeting.
- NASA promotes ED events and opportunities through NASA EXPRESS and other media.

The second type of relationship relates to management, regulatory, and operational issues impacting federal agencies that provide education programming. In these meetings, participants identify, propose, and provide mutual support in implementing solutions to common issues impacting efficiency and effectiveness.

- Federal Interagency Committee on Education (Chaired by ED);
- Academic Competitiveness Council (collaboration on development of STEM evaluation measures);
- NSTC Subcommittee on Education, including development of the "Finding What Works" publication;
- NSTC Subcommittee on Innovation and Competitiveness;
- Federal Evaluators informal association;
- Working groups related to data collection, privacy issues, performance and assessment reporting, other issues; and,
- ED personnel development details at OE.

Upcoming opportunities for collaboration between NASA and ED include but are not limited to:

- Dr. Lach has expressed interest in participating in an upcoming Education Launch Forum, hosted by the AA for NASA Education. Dr. Lach was scheduled to present at the STS-131 forum on attracting girls to STEM study but was unable to participate.
- NASA is considering a STEM summit with ED and other science mission Agencies (e.g. Energy, NIH, NOAA, NSF) on how to motivate students to pursue STEM careers. Focus will be on using research data and evidence to determine what works and next steps.
- Stakeholders may conduct joint technical assistance webcasts to ED and NASA grantees. This assistance will promote better use of existing STEM resources and encourage collaboration.
- NASA has an infrastructure in every state (e.g. Space Grant, NASA Educator Resource Centers) of the Nation, and we can mobilize these resources in support of a national STEM initiative.
- NASA is committed to making it technological assets (ISS, Centers, content), it scientific and technical professionals, and its education infrastructures available to ED and other partners to expand delivery of cutting edge STEM content into every classroom in America.
- NASA is a premiere Federal agency that can help hone the innovative skills of the Nation's college students. NASA can partner with ED-funded students to give them an internship/fellowship experience with NASA scientist and NASA funded projects in universities throughout the country.

46. Given that US student achievement on international assessments of math and science ability has continued to lag for more than ten years, what contribution does astronauts outreach make to inspiring future scientists and engineers in a way that improves US student achievement?

Answer: OE uses the Agency's unique missions, facilities, and people to contribute to increased student interest in STEM. NASA further recognizes that astronauts, their training, and their spaceflight experiences, can be used to engage, inspire, and educate K-12 students in STEM disciplines. NASA astronauts play an important role in the Agency's efforts to inspire the Nation's future scientists and engineers both during space missions (i.e. Space Shuttle and the ISS) and during face-to-face events. Education activities that include astronauts are managed by the Teaching from Space (TFS) and Astronaut Offices at the NASA Johnson Space Center (JSC). NASA's TFS office is located within the Astronaut Office at JSC and works closely with astronauts and their support teams.

Face-to-Face Appearances and Education Events

The Astronaut Appearance at JSC works closely with the NASA Public Affairs Office (PAO) and Astronaut Office management to coordinate requests for astronaut appearances. Due to the extensive mission training requirements and a high demand for astronaut appearances, the Appearance Office can respond favorably to only a limited number of appearance requests. TFS supports education-related astronaut appearances requested by the OE and other educational organizations.

As supply cannot meet demand, NASA has found ways to maximize the excitement generated by astronauts and to leverage astronaut on-orbit activities and public appearances into larger education efforts. TFS develops education resources based on astronaut training and space missions. These resources utilize unique NASA content and are designed to connect students and educators to the Agency's missions. TFS recently developed two comprehensive education Web sites associated with flights of astronauts who are also K-12 educators (Joe Acaba and Ricky Arnold on STS-119, and Dottie Metcalf-Lindenburger on STS-131). These sites provide a "one-stop shopping" resource for education materials and activities related to spacesuits (http://www.nasa.gov/education/spacesuits) and robotics (http://www.nasa.gov/education/robotics). These themes directly reflect the on-orbit activities of the educator astronauts.

To best leverage the appearance of an astronaut at an education event, the appearance itself is usually only one element of an education program being conducted at the host location. TFS identifies and prepares education content and materials appropriate to the audience to whom the astronauts will be speaking. TFS personnel often staff the event and provide hands on engagement activities for the audience. The TFS office also supplies the staff, astronaut, or other NASA speakers with grade-appropriate speaking points and simple demonstration items for use during the event. Astronauts have successfully spoken to students about NASA missions and engaged them on such scientific, engineering topics as spacesuit technologies, rocketry, robotics, and other subjects related to their training and missions. When presenting to educator audiences, astronauts typically provide examples of their learning and training experiences. In turn, teachers are able to engage their students in STEM study by providing examples of connections between academic disciplines and real-life applications. Providing a context for study and promoting career options in STEM fields is an important strategy for NASA education.

As of March 31, 2010, astronauts have participated in 101 education-related face-to-face appearances this fiscal year. The Astronaut Appearance Office does not record actual number of attendees for each appearance. This includes 35 events at K-12 institutions, 55 at colleges and universities, three at informal education institutions, and eight special education events.

Out of this World Astronaut Outreach
Through competitive application processes, NASA Education provides two unique on-orbit education opportunities, In-flight Education Downlinks and Amateur Radio on the ISS (ARISS). Downlinks and ARISS contacts are typically

incorporated into a suite of space-related education activities conducted by the host organizations. Downlinks are video conferences-type events, designed for K–12 educators and students. A key feature of any downlink is an astronaut demonstration of a STEM concept. Downlinks include a questions and answer session between students and the astronauts. During an ARISS contact, education organizations use amateur radio technology to connect students with astronauts on the ISS. Students ask questions about space exploration, space-based research, living and working in space, and space-related careers.

Testimonials
Throughout their careers, it is not unusual for astronauts to develop a close personal relationship with a particular school. After an education-related appearance, several astronauts remained in contact with the school and have become virtual pen pals with educators and their students. In some cases, the astronaut has arranged to bring special school items with them on their flight missions. Educators have expressed the value of astronaut educators in inspiring students.

- In 2004, Astronaut Sandra Magnus accepted a speaking invitation at Wendover High School in Wendover, UT. This activity developed into a long-term relationship with one of the school's teachers. In 2009, while Magnus was on the International Space Station, she communicated with students and flew a student-made flag. The teacher wrote, "She (Magnus) has really cared about my students and desired to inspire them. … I was so proud to have her convey that yes, students can reach for their dreams and have them come true."
- Astronaut Danny Olivas, a native of El Paso, TX, has taken a special interest in educators and students in the El Paso Independent School District. Olivas has developed a close relationship with the district and has been instrumental in involving its students and educators in multiple NASA education activities. One district employee described the impact of one of his visits: "He said good morning to the boys and girls and then walked through the school in his flight suit, popping into classrooms and high-fiving kids. You could hear cheering and shouting all the way to the office."
- Astronaut Jim Dutton recently circled the Earth as a crewmember on STS-131, and many students closely followed his mission. Mountain View Elementary School in Colorado Springs, CO, has "adopted" the astronaut and hosted speakers and special activities related to space exploration. A fifth grade class at the school developed a Web site (http://www.goJIMDUTTONgo.com) to showcase its connection with Dutton and the STS-131 mission. Dutton plans a video conference with the students following his mission.

47. Is there more than anecdotal evidence of the positive effects of astronaut visits to schools and other student interactions; if so, please outline this evidence?

Answer: In FY 2010 astronauts have so far conducted eight education downlinks and five ARISS contacts in the United States. After each of these events, NASA administers a short survey to student and educator participants through the on-line Office of Education Performance Measurement (OEPM) system. Students and educators respond to questions related to the event's education value.

On March 31, 2010, information about downlinks and ARISS was extracted from OEPM and assessed. Student survey data show:

- 848 student surveys have been completed.
- 85.5 percent of students "agree" (46.8 percent) or "strongly agree" (38.7 percent) that they learned something new about NASA as a result of the event.
- 70.8 percent of students "agree" (39.4 percent) or "strongly agree" (31.4 percent) that they enjoy learning when NASA materials and content is used.
- 86.2 percent of students "agree" (28.2 percent) or "strongly agree" (58.0 percent) that they think NASA does important and exciting work.
- 41.3 percent of students "agree" (22.1 percent) or "strongly agree" (19.2 percent) that this experience increased their interest in a STEM career.

Educator survey data show:

- 87 educator surveys have been completed.
- 79.3 percent of educators "agree" (44.8 percent) or "strongly agree" (34.5 percent) that they could immediately apply what they learned from this NASA experience to teaching about STEM.
- 70.1 percent of educators "agree" (39.1 percent) or "strongly agree" (31.0 percent) that the NASA resources used in the event will be effective in increasing their students' interest in STEM topics.
- 59.7 percent of educators "agree" (33.3 percent) or "strongly agree" (26.4 percent) that they will be more effective in teaching STEM concepts introduced in this NASA experience.
- 42.5 percent of educators "agree" (24.1 percent) or "strongly agree" (18.4 percent) that the activities ideas, or resources could be used to involve families in their children's STEM education.

Similar results were obtained from students and educators participating in the NASA Explorer Schools project. In 2006 and 2007, an independent external evaluator determined that 100 percent of 32 surveyed schools either "agreed" or "strongly agreed" that astronaut-based activities were successful, an effective way to learn, were engaging inspirational to their students, and would lead to more student involvement in STEM.

48. How is NASA involving the Space Grant consortia in efforts to reform STEM education and the inclusion of inquiry-based instruction in K-16 science and engineering education?

Answer: As outlined in the Strategic Coordination Framework of the NASA Education Program, the Agency's primary higher education outcome is to contribute to the development of the Nation's STEM workforce, and the primary outcome in K-12 STEM education is to attract and retain students in STEM disciplines. To achieve these outcomes NASA implements a progression of educational opportunities for students, teachers and faculty. Accordingly, all NASA higher education and K-12 education projects are required to contribute to the advancement of STEM education, and a significant portion of that contribution is applied to the reform of STEM education through support for inquiry-based instruction in K-16 science and engineering education.

With its broad mandate encompassing higher education, K-12 education, and informal education, the National Space Grant College and Fellowship Program (Space Grant) occupies an important position among the NASA education projects aligned with STEM reform efforts. Space Grant offers resources and geographic reach from universities down into local schools. To leverage this network, NASA K-12 and informal education investments are designed and implemented to include competitive opportunities for Space Grant participation. Examples of inquiry- and project-based NASA K-12 education investments that utilize the unique capabilities and reach of Space Grant include:

- *Interdisciplinary National Science Program Incorporating Research Experience (INSPIRE):* To support implementation of a two-week residential college STEM experience for high school students in the INSPIRE project, NASA has awarded cooperative education grants to the University of Puerto Rico, Rio Piedras; South Dakota School of Mines and Technology; and Virginia Polytechnic Institute and State University, all of which are members of Space Grant. Space Grant students are also being encouraged to serve as near-peer mentors to INSPIRE high school students.
- *Aerospace Education Services Project (AESP):* In the past two years, Space Grant has partnered with AESP to improve professional development for teachers. The organizations released competitive opportunities for mini-grant awards to develop new pre-service or in-service educator courses or workshops based on NASA content. Eligible institutions were colleges, universities and non-profit organizations that were in good standing of the Space Grant network. The 11 institutions in this mini grant activity fund development of professional development

courses using education resources already developed by NASA, supplemented with materials from other space education programs.

- *K-12 Competitive Grants:* The K-12 Competitive Grants Opportunity is a NASA education project that supports new, innovative, and replicable approaches to improving STEM learning and instruction at the elementary and secondary school level. Space Grant consortia are eligible to serve as co-investigators for awardees, and consortia members who qualify as non-profit institutions may also participate as primary investigators. The Virginia Space Grant Consortium was selected for award under the 2008 competitive grant opportunity and implemented the Virginia Aerospace Science and Technology Scholars (VASTS). The VASTS included an online course in STEM skills (for high school juniors), and provided a follow-up one-week residential program at NASA Langley Research Center (LaRC) for selected students. Following the successful year one implementation, the Virginia Space Grant has now engaged with other Space Grant consortia for potential replication of this model in other States. The West Virginia Space Grant has announced intentions for implementing a project based on this model in the next academic year.
- *Summer of Innovation (SOI):* In response to a national need identified by the NASA Administrator, NASA is launching a SOI pilot program in FY 2010. The established and in-place state-based networks and partnerships with formal and informal education providers established Space Grant consortia as ideal implementers of this pilot project. Proposals were received from 31 state consortia. NASA announcement of selected projects is expected in April 2010.

Through Space Grant, NASA provides undergraduate and graduate students with authentic, hands-on experiences drawn from and supporting NASA missions. Working on actual flight projects, students use hands-on experiential learning in applying their academic knowledge in STEM to integrated real-word applications. In many cases, the impact is multiplied, as higher education student teams often actively engage and mentor K-12 students in similar efforts.

- *BalloonSats:* The NASA BalloonSat High ALtitude Flight (BHALF) competition, is implemented by Glenn Research Center (GRC), JSC, TFS, and the Ohio Space Grant Consortium. It is an opportunity for students to experience an authentic flight mission, like that of a sounding rocket, from start to finish.
- *High Altitude Student Platform (HASP):* This project provides students with flight opportunities that are intermediate between small latex sounding balloons and Earth orbiting satellites. Student teams compete to provide experiments to fly on the HASP payload. The Louisiana Space Grant consortium manages the project.
- *The NASA University Student Launch Initiative (USLI):* This competition challenges university students to design, build and launch a reusable

rocket. Externally imposed requirements and constraints on the rocket system (e.g. reaching one mile above ground level, carrying a specific scientific payload) encourage students to inquire, analyze, iterate, and make design trade-offs. The eight-month systems engineering project models NASA's technical review processes. In preparation for the activity, the Alabama Space Grant Consortium provides content and conducts workshops for participating university teams. More than half of the participating teams receive sponsorship from their state-based Space Grant Consortia.

- *RockSat and RockOn:* These projects give participating students the opportunity to develop and fly experiments aboard NASA sounding rockets launched from the NASA Wallops Flight Facility in Virginia. Participation is open to students and faculty at universities and colleges. The projects are a cooperative effort between the NASA Wallops Flight Facility, the Colorado Space Grant and the Virginia Space Grant consortia.
- *Integration of Design and Hands-On Learning into Early Stages of Engineering Curriculum Workshop*: Sponsored by the Great Midwestern Space Grant Region, this workshop is designed to provide faculty with knowledge of introductory engineering design and hands-on experiences that can be integrated into engineering programs. The workshop is particularly suitable for institutions that are seeking to emphasize and integrate hands-on training and implementation of system design, simulation, building and testing. Participants are drawn from freshman and/or sophomore engineering programs of four-year university bachelor's degree programs, associate degree engineering programs in community colleges, and two-year institutions.
- *CubeSat Launch Initiatives:* In November 2010, NASA will launch small research satellites as part of the Agency's Educational Launch of Nanosatellite, or ELaNA, mission. The satellites, called CubeSats because of their shape, are projects from Montana State University, the University of Colorado, and Kentucky Space, all members of Space Grant consortia. Of note, Kentucky Space has a core mission that includes engaging K-12 students in inquiry, scientific and engineering design processes.
- *NASA Academy:* The NASA Academy is an intensive 10-week summer institute of higher learning for highly motivated undergraduate and graduate students. The academy recognizes high performing undergraduates as possible leaders in aeronautics and space exploration and provides them with a view into the functioning of NASA, the university research community, and the private industry sector. Instruction includes analysis of how organizations set their priorities and contribute to the success of the aerospace program. The academy teaches leadership through workshops and experience. The NASA Academies are co-sponsored by the participating NASA Centers and Space Grant.

GLOBE

49. How much is NASA planning to spend on the GLOBE Program in FY11, how will any funding above the requirements of the cooperative agreement with UCAR be spent, and are other agencies expected to meet the costs of UCAR support for their activities?

Answer: Consistent with the NASA FY 2011 budget request, the Agency plans to spend \$5.0M on the GLOBE Program in FY 2011. The FY 2011 budget request for NOAA contains no funds for GLOBE (though GLOBE does have the opportunity to secure NOAA funding through NOAA's competitive grants programs). NASA is prepared to provide at least \$4.4M to UCAR for GLOBE Program Office in FY 2011 for the continued support of GLOBE. The remainder of the funds will be used for support of participating NASA scientists, the development of student data entry via handheld devices, and possibly competitive awards for systemic incorporation of GLOBE content by school districts and/or States in the U.S.

50. How is NASA reinforcing the GLOBE Program through its other educational and other activities and how is GLOBE reinforcing other NASA activities?

Answer: NASA supports the GLOBE Program through both the Science Mission Directorate's Earth Science Division and the Office of Education. The intent of the GLOBE program is to strengthen STEM education through hands-on, real-world investigations of the Earth's environment and, when appropriate, to also support satellite data validation with ground-truth measurements.

The GLOBE program is responsive to national education priorities, inquiry-based science learning, students' use of real data, and student involvement in data collection for science investigations. Many of the NASA-funded educational endeavors make use of GLOBE measurement protocols and/or include collaboration with GLOBE partners. Examples include the education and public outreach (E/PO) components of NASA Earth science missions such as Terra, Aqua, Auro, CALIPSO, CloudSat, LandSat, etc. A number of the projects in NASA's recently established Global Climate Change Education portfolio also make use of the GLOBE materials and, in some cases, expands the GLOBE community. Without re-inventing the wheel and re-creating learning materials, GLOBE and these projects help reinforce the agency's objective of building the STEM pipeline.

NASA reinforces the GLOBE program through its continued emphasis on the need to study the Earth and global environment as a system and provision of a comprehensive set of satellite-based observations, particularly the juxtaposition of the local, regional, and global contexts. For the GLOBE Student Climate Research Campaign (SCRC) currently under planning, NASA will also help integrate any of NASA's new data and analysis tools with the GLOBE infrastructure, assuming that the GLOBE community finds them useful. Furthermore, as the Decadal flight missions get underway, NASA will promote the involvement of GLOBE in respective E/PO activities and share the science results and resources with the GLOBE community.

As GLOBE has demonstrated in the past, some of the GLOBE data taken by students are of sufficient accuracy and/or precision and, thus, lend to scientific publications. The small-scale variability in student data from the ground has also been exploited, such as in validating the tree cover and impervious cover data products from LandSat. NASA will continue to promote and reinforce such endeavors, particularly in the GLOBE Student Climate Research Campaign.

These scientists advise on the development of research questions for the SCRC, bring relevant NASA data and research results to bear, and contribute to the GLOBE Scientists Blog. The expertise of the recruited scientists to date has been primarily in atmospheric science. Expertise coverage will expand beginning in FY 2010 to include terrestrial and oceanic sciences.

The Science Mission Directorate supports mission-specific activities to validate satellite data using ground-based observations. Multiple NASA Earth science missions collaborate with GLOBE and make use of GLOBE measurement protocols in their education and public outreach (EPO) endeavors. For example,:

- The CALIPSO EPO team works with scientists from the CALIPSO satellite-based research mission, teachers, and students to better understand the effects clouds and aerosols have on Earth' atmosphere. Students nationwide use GLOBE atmospheric protocols and a sun photometer to obtain aerosol optical depth measurements from their schools and homes for comparison with data collected by CALIPSO.
- The Terra and Aqua missions have supported the S'COOL (Student Cloud Observations On-Line) project in making use of GLOBE protocols and validating satellite observations of cloud cover taken by the CERES instruments. Intensive Observing Periods are announced with wide participation by teachers and students worldwide. GLOBE Contrail Count-a-thons have also been conducted as part of the S'COOL project.
- In collaboration with the National Park Service and GLOBE, the LandSat EPO team has been working with teachers and students on the validation of tree cover and impervious cover data products from LandSat in the upper Delaware River Basin. (See "Bridging the GAPS from Space: How to Validate NASA Satellite Data in the Field"; also, an article on the Landsat website at http://landsat.gsfc.nasa.gov/news/news-archive/news_0041.html.) NASA scientists conducted similar activities during the 2010 Earth Day Celebration on the Smithsonian Mall when more than 400 students from Washington, DC, visit the NASA Village on April 22, 2010.

- The GLOBE UV Radiometer Project was designed specifically in conjunction with the Aura satellite in order to provide a low-cost instrument for data validation. The Aura, CALIPSO, and CloudSat EPO teams have also conducted join teacher workshops using GLOBE protocols and will continue to do so.

The Office of Education funds five Global Climate Change Projects that use GLOBE data, protocols, and/or training. These projects were competitively selected through the Office of Education's Global Climate Change Program,:

- Global Climate Change Institute for Teachers (GccIFT), Improving the Scientific Literacy of K-8 Teachers in the Pacific North West (Western Oregon University): The University seeks to become a GLOBE training center.
- Inspiring Climate Education Excellence (ICEE): Teacher Professional Development for Effective Instruction in Climate Science Literacy (University of Colorado): The target audience is middle and high school teachers whose students are participating in the GLOBE Climate Change Research Campaign.
- Earth System Science – A Key to Climate Literacy (TERC; formerly the Technical Education Research Centers): Develop a web-based module of nine sequential, inquiry-based lab activities that introduce students to Earth system science and climate change. The activities are based on the Exploring the Connections activities from the "Earth as a System" chapter of the GLOBE Teachers Guide.
- Eco-Schools USA Climate Change Connections: Integrating climate change science and applications within the Eco-Schools framework into classrooms using NASA data, protocols and educational resources (National Wildlife Federation): Work with NASA scientists and education specialists from EOS missions including ICESat, Aqua, Aura, Terra and Landsat, as well as with staff from NASA's POWER and GLOBE projects. Develop GLOBE protocols on school energy use in coordination with POWER to enhance the Eco-Schools energy assessment for 25 teachers from Chicago, Boston, Seattle, Houston and Washington, D.C; develop a citizen science monitoring and community service program utilizing NASA's GLOBE program and the Chicago Botanical Garden's citizen science project, Project Budburst.
- Climate Change, Adaptation, and Mitigation in Prince William Sound (Chugach School District Alaska): Elementary and secondary teachers will be trained in GLOBE climate measurement protocols and other NASA climate education data and resources. Teachers implement interdisciplinary climate science activities and units in the classroom and participate in GLOBE climate measurement activities. Community members are invited to participate in organized climate science activities and data collection.

51. In the OSTP developed plan for GLOBE implementation and governance, NASA is retaining responsibility for the cooperative agreement with UCAR; what are NASA's plans for this agreement, when will it be recompeted, and should any of its content, such as data archiving and Web services, be transferred to a government entity?

Answer: In support of the recommendations made by OSTP in its April 2010 report to the Congress concerning GLOBE, NASA will work with NOAA to share the leadership of the interagency Executive Management Board, assuming shared and stable support from the two agencies for GLOBE core operations in future years.

NASA has begun to undertake the development of GLOBE student data entry via handheld devices. NASA has also begun to examine the option of transferring the data and management system functions and web services from UCAR to NASA; in collaboration with UCAR, NASA will conduct a thorough analysis of the overall operational and financial benefits of such a transfer. Given that UCAR has been funded by the NSF to evaluate the effectiveness of the tools to be available from a GLOBE Student Research Collaboratory under its Integrated Technology Experiences for Students and Teachers (ITEST) solicitation, some web services are expected to remain at UCAR. Decisions will be made in collaboration with the GLOBE Program Office at UCAR, NOAA and NSF, to optimize continued support to the GLOBE communities worldwide.

Under the auspices of the GLOBE Executive Management Board, NASA will examine the relative merits of different GLOBE implementation options: fully Federal, fully outsourced to a non-Federal entity, and a Federal-non-Federal partnership. If involvement of a non-Federal entity is deemed desirable, whether in full or in part, NASA plans to recompete the cooperative agreement (CA) in time to start when the current CA expires in 2013.

Space Grant

52. As NASA iterates Space Grant proposals prior to funding, what are the agency's priorities and how are the intended missions of the consortia affected by funding levels?

Answer: The goal of Space Grant is to contribute to the Nation's science and engineering enterprise by funding education, research, and informal education programs. Space Grant is a university-led, State-based consortia of colleges and universities, industry, and State and local government that works with NASA to implement suite of activities that engage learners in each State. Space Grant is primarily a higher education program, supporting undergraduate and graduate research activities, internships, student flight activities (e.g. balloons, sounding rockets), NASA and space-themed for-credit courses, and other types of support for aeronautics- and space-related student pursuits. Space Grant demonstrates success by contributing directly to the NASA, aerospace, and U.S. STEM workforce, inspiring pursuit of advanced degrees, providing hands-on science and engineering opportunities, and enabling student technical publications and presentations.

Every five years, Space Grant awards are made to a lead institution for each State. OE consults with Mission Directorates (MDs) regarding priority R&D requirements, needs, and potential resources. This information is included in the Space Grant Training Grant Announcement of Opportunity and establishes a baseline for a "relevance to NASA" criterion in assessing proposal merit. In responding to the announcement, each Space Grant lead institution must consider the needs and resources of his or her state and submit a proposal that describes how the consortium will increase the understanding, assessment, development, and utilization of space and aeronautics resources. Outcomes must be designed to benefit the state, the student, the Nation, and NASA. A projected five-year budget is included.

Available funding changes annually, so each year, the Space Grant consortia are required to submit a new proposal and operational budget. The budget request and operating plan reflects how funds will be used in that fiscal year. Adjustments may include increases or decreases in number of student fellowships supported, the number and/or magnitude of student research awards, etc. Increases in available funds typically increase the number of students that can be supported with significant awards. Release of NASA funds to a consortium is subject to continued demonstration of adequate progress against goals, objectives, achievement of expected outcomes, and receipt and approval of a modified annual budget.

The modified budget and proposal submission also allows consortia to respond to NASA-identified R&D or education priorities and strategies. Space Grant consortia directors are advised through updated announcements, annual meetings, email notices, and other forms of direct communication.

When NASA released the FY 2010 call for Space Grant annual proposals and budgets, NASA included several suggestions on how activities could be aligned to Agency educational and R&D priorities. Individual consortia do not provide activities in all of these areas. Implemented projects reflect state priorities, needs, partnerships and other resources specific to that state/consortium.

The FY 2010 priorities for Space Grant included:

- Providing authentic, hands-on student experiences in science and engineering disciplines. This means the incorporation of active participation by students in hands-on learning or practice with experiences rooted in NASA-related, STEM-focused questions and issues and the incorporation of real-life problem-solving and needs as the context for activities.

- Engaging middle school teachers in hands-on curriculum enhancement capabilities through exposure to NASA scientific and technical expertise. Providing capabilities for teachers to provide authentic, hands-on middle school student experiences in science and engineering disciplines (see above).
- Developing new relationships with community colleges and sustaining and strengthening existing institutional relationships with community colleges.
- Supporting aeronautics research in traditional aeronautics disciplines; supporting research in areas that are appropriate to NASA's unique capabilities; directly addressing the fundamental research needs of the Next Generation Air Transportation System (NextGen).
- Supporting environmental science and global climate change research and activities to better understand Earth's environments.
- Achieving and/or maintaining diversity of institutions, faculty, and student participants.
- Enhancing the capacity of institutions to support innovative research infrastructure and providing activities to enable early career faculty to focus their research toward NASA priorities.

Aviation

53. What technologies and other developments are needed to allow unmanned aerial vehicles to fly routinely in FAA controlled airspace?

Answer: Existing Federal air regulations, procedures, and technologies do not allow routine unmanned aircraft systems (UAS) access to the national airspace system (NAS). The Federal Aviation Administration (FAA) has established a process enabling government agencies to request a Certificate of Waiver or Authorization (COA) to operate a UAS in the NAS. The COA process is extremely resource-intensive and lengthy. Additionally, COAs are restrictive and often lack the flexibility to meet the needs of complete missions. For non-governmental civil UAS operations in the NAS, an Experimental Certificate (EC) is required. ECs are limited to an individual vehicle, rather than to a class of vehicles, and severely limit the use of the UAS. As a result, it is highly unlikely that a UAS commercial industry will emerge without the ability to routinely access the NAS.

In order for UAS to operate routinely and seamlessly in the NAS, some major technical problems have to be overcome. The most relevant of these include ensuring safe separation of UAS vehicles from other existing air traffic, including the ability of these vehicles to detect and avoid other vehicles either using capability onboard the vehicle or through a pilot on the ground flying the vehicle remotely. In order to fly these vehicles safely and remotely, robust communication links must be in place to ensure the safety of the vehicle and all vehicles flying in the airspace. Human and machine interface issues for remote pilots flying these vehicles are also an area of great concern, as well as the roles and responsibilities between human operators (pilots and controllers) and automation that will be needed to enable UAS access to the airspace. In addition, certification and safety methodologies need to be established, to not only enable UAS access to fly in the airspace, but to ensure the safety of all vehicles flying in the airspace as well. NASA Aeronautics Research Mission Directorate's new initiative for UAS Integration in the NAS is planning to address these key technical challenges.

In response to these challenges and the growing demand for UAS NAS access by government agencies, the FAA and Department of Defense (DOD) formed an executive committee (UAS EXCOM) and have invited NASA to participate. The UAS EXCOM is comprised of senior executives from the FAA, DOD, NASA, and the Department of Homeland Security. The UAS EXCOM will provide the strategic vision for safe NAS access for government-operated UAS that is essential to creating a technology development roadmap to focus the development and transfer of concepts, technology, algorithms, and knowledge to the FAA and other stakeholders to ultimately enable routine UAS NAS access for all users.

54. What are the explicit goals of the green aviation program, including fuel efficiency, decreased carbon footprint for passenger and cargo aviation, decreases in flight and ground operations time, and what to what milestones is the program targeted?

Answer: "Green aviation" research within the Aeronautics Mission Directorate spans three major research Programs: the Airspace Systems Program; the Fundamental Aeronautics Program; and the Integrated Systems Research Program.

The Airspace Systems Program (ASP) does not have specific goals for decreasing flight and ground operations time and aviation environmental footprint. However, NASA systems analysis indicates that new operational procedures currently in development within ASP have the potential, if fully adopted into the National Airspace System, to reduce fuel burn by 400 million gallons per year during landing and takeoff phases of flight and an additional 200 million gallons per year during the enroute cruise phase of flight. Each gallon of conventional jet fuel burned releases 21 pounds of carbon dioxide into the atmosphere. These savings correspond to about 3 percent of the annual fuel burned by U.S. commercial airlines. While some "green operations" procedures have already been certified and are being used, the FAA estimates that the implementation of the full spectrum of NextGen-enabled "green operations" will not be in place until 2035 and that the potential fuel burn savings at that time could be more than 1 billion gallons per year.

Improvements in ground operations being developed within the ASP Program have the potential to reduce fuel burn during airport taxi operations by 15 million gallons per year, which would result in a reduction of 2 million pounds of CO_2 per year of harmful emissions in and around our largest airports. Research within the ASP Program focuses on developing new capabilities in traffic flow management, dynamic airspace configuration, separation assurance, super density operations, and airport surface operations, on the transition from the laboratory to the field of key systems concepts, and on demonstration of these integrated capabilities in relevant flight environments. All of these efforts are aimed at maturing new operational concepts to the point at which they can be turned over to the FAA, aircraft operators and industry for implementation and certification decisions.

The Fundamental Aeronautics Program (FAP) and Integrated Systems Research Program (ISRP) conduct complementary research aimed at reducing the environmental impact of aviation through reductions in noise, emissions, and fuel burn of aircraft. New concepts and technologies undergo early-stage development within the FAP Program. Individual technologies which have matured and show potential for reducing noise, emissions, and fuel burn are then evaluated at an aircraft system level in relevant environments (including flight test) within the Integrated Systems Research Program (ISRP). Technologies that have been successfully demonstrated within the ISRP Program will be ready for implementation and certification by aircraft and engine manufacturers. FAP and ISRP program goals are to develop and demonstrate new technologies for transition to industry by 2020 that can achieve the following:

- Reduce fuel burn (and thus CO_2 emissions) of new aircraft by 50 percent relative to that of new aircraft commissioned in 1998.
- Reduce NO_x [nitric oxide (NO) and nitrogen oxide (NO_2)] emissions by 50 percent relative to currently operational aircraft.
- Reduce the area of objectionable noise around airports to one-sixth of what it is today.

The environmental impact of aviation will be reduced over a number of years as new vehicles with these performance gains enter the fleet and older vehicles are retired. Near-, mid- and long-term objectives toward these goals are described in the National Plan for Aeronautics Research and Development and Related Infrastructure.

The FAP and ISRP Programs are also performing research on alternative fuels such as those derived from coal, natural gas, and biomass. This research is aimed at understanding the emissions and combustion characteristics of these fuels and developing methods of designing fuel-flexible combustors for future aircraft engines that are capable of safely operating on both conventional and alternative fuels.

55. What are the explicit responsibilities of NASA in the deployment of NextGen?

Answer: NASA's Airspace Systems Program (ASP) is a principal source of air traffic management research at the fundamental level. As such, ASP has no responsibilities for deployment of operational capabilities in the National Airspace System. To meet the expanded needs of NextGen, however, it is important that NASA's fundamental research efforts targeting NextGen operational requirements are identified, conducted, and effectively transitioned to the FAA for certification and implementation.

With this in mind, and working collaboratively across agencies, FAA and NASA have established four Research Transition Teams (RTT) to effectively manage and foster cross-agency interactions. The RTTs are designed to coordinate the development of key research requirements and to better coordinate the evolution of research into operational improvements and new capabilities. The RTTs build upon the FAA's prior successful deployments of NASA-developed technologies, such as the Traffic Management Advisor with enhancements for major metropolitan areas and surface management tools. The four teams cover near-, mid-, and long-term capabilities stretching from the enroute airspace to the terminal and surface including traffic flow management. The near-term focus is the technology transfer of mature concepts and research; for mid-term capabilities, the FAA and NASA are now jointly engaging earlier in the research to develop the products needed for transfer; and for long-term capabilities, the FAA is providing NASA with subject matter expertise to support the research.

By engaging the FAA earlier in the formulation of NASA's research, the FAA and NASA are able to better synchronize their plans to ensure that NASA-developed products meet the needs of NextGen, are evaluated and tested in relevant operational environments, and can be successfully implemented by FAA.

Through coordinated planning, the RTTs show good integration between implementation and research organizations. The current teams do not cover the whole range of NASA activities or the FAA's implementation plans, and so more teams may be added as the body of ASP research work grows and as future needs are identified.

Both the FAA and JPDO have been publically supportive of the RTT activities and recent products. Numerous FAA organizations are invested in RTT formulation and execution with both personnel and resources. This has also been reflected in FAA testimony before the responsible Congressional oversight Committees.

Space Station

56. What will be the primary focus of astronaut activity at the Station, and how will this further human space exploration?

Answer: The ISS multinational crew (U.S., Canadian, European, Russian, and Japanese) is now composed of six members serving approximately six-month rotations onboard. Typically, there will be two U.S. astronauts in this complement based on provisions of the bilateral MOUs (this can vary to some degree under unique circumstances associated with barters, or due to optimization of crew exchange operations). The crew performs as an international cadre supporting tasks that span across the mission requirements of all partners. Their primary responsibilities are continuing safe operation of the spacecraft and maintaining spacecraft performance in support of science & technology (S&T) mission objectives. The crew is actively engaged in the S&T operations -- they both operate S&T payloads in accordance with requirements and can serve as test subjects in the case of the human biomedical research program. Within the five-year horizon of the budget, the crew will support efforts funded by an additional $1.2B for life extension, $1.3B to increase ISS functionality, and $800M to enable full utilization of ISS.

Crew operating experience on the ISS includes real-time system diagnostics in response to anomalies as they arise (i.e., "trouble-shooting"), removal and repair of critical system components, routine servicing and maintenance, and S&T payload procedural execution. In this latter case, the crew members can communicate directly with ground-based scientists and technologists to perform research in an interactive mode that is far more productive than has been previously achievable on intensively time-lined short-duration missions. As human exploration proceeds, the real-time operating experience gained by multinational crews on the ISS will be directly applicable to future challenges in systems maintenance and research operations beyond LEO. In many cases, these are the same crew that will take the next steps in human exploration over the coming years and the proficiency levels achieved on the ISS will directly benefit the success of human missions beyond LEO.

57. As the station could serve as an assembly point for missions beyond low Earth orbit and on-orbit fueling, will it still be there when we are ready to use it in this way?

Answer: The ISS Program partners have analyzed the technical aspects of ISS operations and determined that there are no technical constraints to extending ISS operations to at least 2020. Current plans for important flagship technology demonstrations are planned within this timeframe and will rely upon the ISS. Additional activities and further extension of the ISS would necessarily involve an assessment of benefits versus costs based on a specific set of mission objectives to be pursued. As future exploration missions evolve and are ultimately resolved, the ISS program is prepared to participate in these discussions and ensure that the technical and cost information is available to support fully informed objective decision making in the future.

58. What will limit the useful life of the station, and when will we and our partners be forced to safely deorbit it?

Answer: NASA is currently analyzing the life expectancy of the ISS along with the International Partners (IPs) through 2028, which is a 30-year certification life from the launch of the initial element in February 1998. The analysis includes such items as expected failure rates, structural integrity, operational cycles, external environment, external and internal loads. The analysis is being performed on all pressurized elements, truss segments, other structural elements such as docking systems and rotary joints, fluid systems, electrical components, computers, replaceable units, power generation, heat rejection systems and all other systems. To date, NASA and the IPs have not identified any module, component or system that would prohibit the useful and safe operation of the ISS beyond 2020. Based on this analysis and the actual performance of the on-orbit platform over the next few years, the ISS Program will be able to identify the elements that would limit the operation of the ISS beyond 2020. Without demonstrated on-orbit performance of the ISS systems and elements, it would be very difficult for NASA to predict with certainty the life expectancy of the ISS. At some point in the future a trade between maintaining the ISS and replacing the non-functioning elements versus safely de-orbiting the ISS will have to be considered. This trade would have to be conducted across the ISS partnership along with NASA's stakeholders including the White House, Congress, and the utilization and science communities.

59. What are NASA's plans to reestablish a vibrant program in space life and physical sciences; how much is requested for this in FY 2011 and projected for future years. How many investigation grants are anticipated?

Answer: The NASA FY 2011 budget request allocates $50M/year for basic research in biological and physical sciences, up from $25M in the FY 2010 request. Last year's budget level ($47 M) supported about 100 investigations in life and physical sciences, which included both flight and ground studies.

NASA is awaiting an interim report in late May 2010 from the NRC on the progress of their Decadal Study on Biological and Physical Sciences. This is a necessary prerequisite to further definition of the breadth and depth of the future research program. We anticipate that the NRC will provide research priorities that will guide NASA in re-positioning the ISS for a robust program over the coming decade.

60. What role do space life and physical sciences play in developing enabling technology for future human exploration beyond low Earth orbit?

Answer: Long-duration spaceflight beyond LEO exposes the human body to an unfamiliar environment, and the effects of that environment must be studied to be fully understood, and, in some cases, countermeasures must be developed and instituted. For instance, the effects of extended exposure to microgravity include loss of bone and muscle mass. These medical phenomena have been observed in the United States and Russian space programs since the days of the Skylab and Salyut space stations. Today, some of the most important experiments being conducted on the ISS are in the area of biomedical research that will enable astronauts to live and work for longer periods of time in space. Radiation is also a concern for space travelers, particularly when missions are required to fly beyond the protection of the Earth's magnetic field. Different types of radiation require different kinds of shielding, and risk reduction efforts therefore include studies into both medicine and materials. Understanding radiation effects and shielding to counter those effects is critical in preparing for long-duration missions beyond LEO.

The FY 2011 budget request increases NASA's Human Research Program (HRP) funding to $215M per year – a 40 percent increase over FY 2010 funding. This additional funding will enhance current HRP work and enable creation of more robust exploration-enabling projects, with an increased focus on the following areas:

- <u>Space radiation research</u> to expand the knowledge base and reduce the uncertainty inherent in current radiation exposure limits for astronauts, leading to the development of radiation countermeasures. This work will be in coordination with space radiation protection demonstration projects by providing the latest progress on human vulnerabilities to the space environment.
- <u>Biomedical technology research and development</u> that supports long-duration human spaceflight (and may also have applicability to public health care needs) in areas like advanced medical care technology and bioinformatics.
- <u>Research into human behavioral factors and psychological implications</u> of long-duration spaceflight, and development of countermeasures to mitigate the risks of degraded human performance.

With regard to physical sciences research, NASA is working on:

- Research in combustion sciences focuses on providing improvements in accuracy of kinetic parameters and transport properties for modeling flame conditions. This will lead to more reliable and efficient spacecraft fire prevention, detection and suppression systems.
- Fluid physics investigations identify the gravitational mechanisms in multiphase phenomena (adiabatic and boiling) and develop a predictive

framework for space system design. Findings of these investigations will provide a critical validation of components and subsystems that will enable life support, power, and propulsions systems to reliably operate at higher efficiencies in 0-g and possibly to be designed at a lower mass than the current operational systems today.
- Research efforts in Fundamental Physics will lead to new understanding and discovery of fundamental laws of physics and organizing principles including Einstein's relativity theories, Equivalence Principle, Standard Model, time-dependence of fundamental constants, and Newtonian gravity. These efforts will help regain U.S. global leadership in precision frequency and time-keeping technology by deploying most advanced clocks onboard ISS.
- Expanded opportunities in materials science research will result in advances in areas of metals, alloys, semiconductors, glasses, and ceramics. This research may identify means for Earth-based application improvements in materials processing leading to new materials and improved process yield.

NASA's biological research encompasses studying how life adapts and evolves in space. With regard to biological sciences research, NASA is working on:
- Microbial Research will focus on areas such as clarifying the mechanisms for spaceflight-induced increases in microbial virulence and developing an understanding of microbial biofilm production during spaceflight and associated mitigation strategies. Other areas of study requiring animals include invasive putative countermeasure development and tests to reduce cancer incidence, space flight osteoporosis, infectious diseases and ecological conservation. Future ISS research promises even more as the full capabilities of ISS become more utilized.
- Animal research, complemented by investigations using cells and tissues, will clarify basic mechanisms of how the musculoskeletal and sensory-motor, endocrine, neural, and other physiological systems are affected by spaceflight, as well as to understand the effects of gravity on how wounds heal at the cellular, organ, tissue, and whole animal level.
- Plant research using the ISS and ground facilities will help clarify mechanisms of gravitropism, i.e., response of plants to the gravity continuum, from fractional to hypergravity. The absence of gravitational acceleration also provides an excellent opportunity to study plant tropisitc responses to light, water and other environmental stimuli. The use of plants for human life support systems has been discussed for years, but more research is need to understand their capacities and reliabilities for converting light to chemical energy, transpiring (purifying) water, scrubbing and reducing carbon dioxide, and generating oxygen in space settings.

61. Will planned budgets for space life and physical sciences be adequate to fund investigations fully utilizing NASA's portion of Space Station research capacity?

Answer: Fully utilizing the U.S. share of research payload resources will be accomplished through pursuit of: (1) NASA mission-driven research in the areas of human physiology and spacecraft technology, as well as basic science and technology research that feeds these two objectives; and (2) U.S. National research in areas of value to the nation such as, but not limited to, energy, the environment and public health. In this latter category, NASA has already executed agreements with other U.S. government agencies (i.e., NIH, USDA, DOE, NSF, NRL, DARPA), non-profit institutions and private firms to pursue ISS-based research and development. We are confident the U.S. share of the ISS will be fully and productively utilized, and are in the process of determining the ultimate mix of NASA and other National research that will be pursued.

62. What experiments are planned for the AMS should it be successfully launched?

Answer: AMS science operations should be able to begin following a successful installation, activation, and check-out of the AMS on the ISS external truss attach location. Specifically, the multiple AMS sub-atomic cosmic-ray particle detectors will all operate in parallel synergistically to begin the AMS science objectives of searching for evidence of cosmic dark matter, antimatter, strange matter, and other astrophysical particles of interest in our Milky Way Galaxy and beyond. The AMS subatomic particle detectors include a Transition Radiation detector, twin Time-of-Flight detectors, a Silicon Tracker, an Anti-Coincidence Counter, a Ring Imaging Cerenkov Counter, and an Electromagnetic Calorimeter. Functionally, all of the AMS particle detectors survey and collect cosmic-ray particles.

63. During initial planning for the Space Station, physical sciences microgravity requirements were stated as one millionth of a gravity; what are current research requirements and does ISS meet them in any of its facilities?

Answer: The physical science gravity level requirement on the ISS is experiment specific. For example, fluid physics experiments typically require 10E-3 to 10E-4g, combustion experiments typically require 10E-4g, and some materials science experiments require 10E-6g. These various acceleration requirements can often be met by the ISS facility itself or when necessary, by using a facility with an active rack isolation system or passive rack isolation system.

Space Technology

64. Will the new space technology program function effectively as an advanced research projects agency for space – an ARPA-S?

Answer: Yes. The new Space Technology Program will incorporate many of the positive tenets of an ARPA/DARPA type organization in its planning, procurement and program execution strategies. The Space Technology program will increase its support for research in advanced space systems concepts and game-changing technologies, enabling new approaches to our current mission set and allowing the pursuit of entirely new missions. Using an array of management, funding, and partnership mechanisms – some similar to those utilized by DARPA – this program will engage the brightest minds in private industry, across the NASA Centers, and throughout academia. The broadly-applicable technologies proven and matured within the Space Technology Program complement the more mission-focused activities in NASA's Mission Directorates. Together, these programs ensure the development and infusion of innovative technologies and capabilities to reduce the cost and improve the performance of future space science and exploration missions.

Specifically, the Space Technology Program's Game Changing Development element will use an ARPA/DARPA-like "end-game" approach. Research teams will be provided a list of challenge goals with top-level requirements for the desired capability. Under the direction of a Project Manager (PM) who is a technical expert in the subject area, multiple teams (performers) will compete to define solution approaches using advance technology to enable new capabilities that reduce cost and improve performance of space systems. Multiple solution approaches foster innovative, high-payoff, high-impact advances. The PM will be held accountable for ensuring that discoveries will move rapidly from laboratory to application.

Game Changing Development projects are intended to be capability-oriented and differ from traditional R&D methods that advance discipline or core knowledge. Being advanced research projects, the high-risk, high-payoff nature will lead to early completion in some projects. Technical knowledge gained will be used in other projects to continue the rapid development pace. The DARPA process will be used to guide idea generation and selection of high-payoff activities. The products of NASA's Game Changing program foster creation of innovative/high impact capabilities, rapid advancement at the subsystem and/or system level and clear paths to technology infusion.

The Space Technology Program will issue open calls for technology development and demonstration activities. Partnerships between NASA Centers, industry, academia and other government agencies will be encouraged. Game

Changing Development projects may be sponsored collaboratively by NASA and other government agencies, including DARPA.

65. Will the new technology efforts engage the full US R&D community, including universities, industry, and the labs of other government agencies, and how will this be done?

Answer: NASA will seek engagement and input from industry, academia, and other government agencies as we move forward with the Agency's road mapping activities as well as the program planning and development of the Space Technology Program. Subject matter experts from NASA, industry, academia and other government agencies will comprise the teams assigned to develop the cross-Agency technology area roadmaps.

The three elements under the OCT Space Technology Program will issue open calls for technology development and demonstration activities that encourage partnerships between industry, academia and other government agencies. These open calls represent a significant fraction (greater than 70 percent) of the Space Technology Program funding.

Additionally, a key element of the Office of the Chief Technologist organization is the Partnerships, Innovation and Commercialization program. Building on the success of NASA's Innovation Partnership Program, this functional element has the specific responsibility of increasing NASA collaboration with industry, academia, and other government agencies.

NASA's Office of the Chief Technologist is also responsible for re-establishing a program akin to the NASA Institute for Advanced Concepts to engage innovators within and external to the Agency in accordance with the recommendations of the NRC's *Fostering Visions of the Future* report. NASA's SBIR/STTR program is also integrated into the efforts of the Office of the Chief Technologist.

Engagement and collaboration are also a matter of organizational culture. Based on input received from the newly formed NASA Advisory Council Committee on Technology and Innovation, the NASA Office of the Chief Technologist is planning a wide range of activities to improve the collaboration culture of the NASA Centers. This includes increasing our ongoing external outreach activities including workshops, conferences, forums, advisory committee meetings, and symposia as key methods of coordinating and communicating with our external key technology customers and stakeholders as well as making use of Intergovernmental Personnel Agreements and other mechanisms for short-term personnel developmental assignments with other government agencies, academia, and industry.

66. How does the suborbital program of the Office of Science factor into the proposed reemphasis on NASA technology development?

Answer: In addition to their scientific value, the Science Mission Directorate's suborbital programs serve as technology development test beds for new capabilities through maturation of space flight systems. Their airborne, balloon, and sounding rocket program elements provide flights of systems and subsystems that span Technology Readiness Level (TRLs) between the laboratory and spacecraft. Many technologies subsequently used on spacecraft cannot be adequately tested using ground-based methods, so suborbital flights continue to be crucial for providing low-cost, rapid access to the near space environment.

For over five decades, NASA's suborbital program elements have provided vital technical support for NASA's scientific mission success. They have supported a broad range of cutting-edge science and technology, some of which have led to Nobel prizes for research funded wholly or in part by the Agency. They have provided strategic platforms for scientific research and development that reduced mission risk and led to new techniques, technologies, and instruments flown on spaceflight missions. They provide an important part of the training for NASA and academic researchers and engineers, and they are invaluable in enabling the workforce to acquire systems engineering and program management skills.

Without the suborbital program, major Earth Science, Heliophysics, and Astrophysics missions – such as Aura, CALIPSO, Pioneer, Voyager, Galileo, Hubble, Spitzer, and COBE, to name but a few – might not have been as successful. The recent report of the National Academy of Science, *Revitalizing NASA's Suborbital Science Program: Advancing Science, Driving Innovation, and Developing A Workforce*, (NRC, 2010) describes well the importance of suborbital programs to critical technology development for science. For example, the report identifies three-dozen space mission instruments that trace their heritage from balloon suborbital flight programs. The report maps a similar heritage from sounding rocket investigations to subsequent space missions.

NASA's suborbital programs will continue to be a key source of innovation and cost-effective technology demonstration as well as vital scientific assets. NASA's Science Mission Directorate will work with NASA's Office of the Chief Technologist to leverage each other's programs to achieve science and technology development goals.

US Leadership

67. How does the US compare with other countries and regions in the various areas of space activity, including launch capability, human operations in orbit, exploration, remote sensing, and aeronautics?

Answer: By nearly every measure, including governmental budget for civil space and aeronautics research, as well as data generation and publication, the United States presently holds a pre-eminent position among its counterparts in civilian space and aeronautics activities.

68. How is NASA leadership manifested in ways of which the public may not be widely aware?

Answer: NASA's leadership is manifested in a number of ways that the public is not widely aware of. Most Americans closely associate NASA with leadership in the areas of human spaceflight (the Space Shuttle and the International Space Station) and robotic space exploration (Voyager, the Mars rovers, the Hubble Space Telescope, etc.). However, fewer people are aware of NASA's leadership in the areas of aeronautics, Earth science and education.

NASA has made decades of contributions to aviation. Aeronautics researchers continue to transform the U.S. air transportation system into one for the future that meets the demands of today. The Aeronautics Research Mission Directorate's goals are clear—improve safety in aircraft and the airspace in which they fly, improve air traffic management to support increased safety and efficiency, and reduce noise, emissions, and fuel consumption to make aircraft more environmentally responsible. This Mission Directorate already has made important contributions in these areas.

NASA's leadership in Earth science has benefited Americans for decades by maximizing the use of satellites, pioneering a better understanding of how our planet works, and developing new ways of seeing Earth. NASA has been at the forefront of using Earth orbit to get a better view of how weather systems develop, and the United States is a safer place to live as a result. NASA's space-based research into how Earth spins and shifts in its orbit made GPS navigation units possible. And NASA sensors in orbit and aboard aircraft have recently made breakthroughs in monitoring U.S. forest fires and detecting loses to regional groundwater reserves in arid parts of the country.

These and other accomplishments will continue to inspire new generations of scientists, engineers and explorers. One of NASA's most important leadership roles is to encourage America's youth to pursue careers in science, technology, engineering and math. Through participation in important educational initiatives like the Summer of Innovation, NASA is continuing to invest in our Nation's future and sustaining American leadership in space and related fields.

Authorizations and Obligations

69. Which programs, projects, or activities (PPA) proposed in the budget are unauthorized?

Answer: As you know, specific funding authorization provisions of the National Aeronautics and Space Administration Authorization Act of 2008 (P.L. 110-422) are expired. However, NASA believes that all of its activities are authorized pursuant to the National Aeronautics and Space Act (P.L. 85-568) as amended.

71. For each such unauthorized PPA, what was the last authorization (public law reference); the last fiscal year of authorization, and the authorized funding level in the last fiscal year of authorization?

Answer: NASA's last authorization was entitled National Aeronautics and Space Administration Authorization Act of 2008 (P.L. 110-422). The last fiscal year of the authorization act was FY 2009. The table below provides the authorization levels reflected in P.L. 110-422.

Account ($M)	FY 2009 Authorization Amount
Science	4,932.2
Aeronautics	853.4
Exploration	4,886.0
Education	128.3
Space Operations	6,074.7
Cross Agency Support	3,299.9
Inspector General	35.5
Total	20,210.0

70.

71. What was the amount of the appropriation provided for each such PPA for the last fiscal year in which it was authorized?

Answer: NASA's last authorization was the National Aeronautics and Space Act of 2008 (P.L. 110-422), which authorized amounts for FY 2009. The amount appropriated for each PPA for FY 2009, authorized pursuant to P.L. 220-422, is displayed below.

Account ($M)	FY 2009 Appropriation Amount
Science	4,503.0
Aeronautics	500.0
Exploration	3,505.5
Education	169.2
Space Operations	5,764.7
Cross Agency Support	3,306.4
Construction and ECR	-
Inspector General	33.6
Total	17,782.4

72. For each appropriation by major program element, what have been the actual obligation rates by quarter for each of the last three fiscal years, and what are the planned obligation rates for fiscal years 2010 and 2011, also by quarter?

Answer: [Chart showing quarterly obligation rates follows:]

Obs Rates-Cumulative		FY 2007				FY 2008				FY 2009				FY 2010				FY 2011			
Program Year		Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
2007		**12%**	**41%**	**61%**	**90%**	**98%**	**99%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**				
	SAE/ESA	9%	35%	55%	87%	97%	99%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	EXC	16%	51%	70%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	OIG	20%	52%	75%	98%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	ARMD	9%	23%	41%	82%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	CAS/Inst	9%	34%	59%	91%	97%	98%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	EDUC	3%	17%	31%	63%	80%	92%	98%	100%	100%	100%	100%	100%	99%	100%	100%	100%				
	ESMD	8%	24%	48%	83%	97%	98%	99%	99%	99%	99%	99%	100%	100%	100%	100%	100%				
	SMD	10%	46%	62%	89%	98%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	SOMD	17%	54%	71%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
	OIG	20%	52%	75%	98%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				
2008						**12%**	**48%**	**76%**	**97%**	**99%**	**99%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**				
	SAE/ESA					10%	42%	72%	97%	98%	99%	99%	100%	100%	100%	100%	100%				
	EXC					16%	58%	82%	98%	100%	100%	100%	100%	100%	100%	100%	100%				
	OIG					21%	44%	75%	99%	100%	100%	100%	100%	100%	100%	100%	100%				
	ARMD					3%	25%	59%	98%	100%	100%	100%	100%	100%	100%	100%	100%				
	CAS/Inst					12%	40%	70%	97%	99%	99%	99%	100%	100%	100%	100%	100%				
	EDUC					5%	12%	32%	77%	79%	79%	95%	100%	100%	100%	100%	100%				
	ESMD					7%	39%	72%	96%	97%	99%	99%	100%	100%	100%	100%	100%				
	SMD					13%	48%	77%	98%	99%	100%	100%	100%	100%	100%	100%	100%				
	SOMD					16%	62%	85%	99%	100%	100%	100%	100%	100%	100%	100%	100%				
	OIG					21%	44%	75%	99%	100%	100%	100%	100%	100%	100%	100%	100%				
2009										**25%**	**41%**	**76%**	**99%**	**99%**	**99%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
	ARMD									17%	37%	66%	99%	100%	100%	100%	100%	100%	100%	100%	100%
	CAS									20%	40%	72%	98%	99%	99%	99%	99%	100%	100%	100%	100%
	EDUC									7%	14%	33%	83%	99%	100%	100%	100%	100%	100%	100%	100%
	ESMD									23%	39%	71%	99%	99%	99%	100%	100%	100%	100%	100%	100%
	SMD									22%	39%	74%	99%	99%	99%	100%	100%	100%	100%	100%	100%
	SOMD									32%	45%	84%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	OIG									19%	41%	69%	99%	100%	100%	100%	100%	100%	100%	100%	100%
ARRA										**0%**	**0%**	**1%**	**39%**	**59%**	**83%**	**95%**	**100%**	**100%**	**100%**	**100%**	**100%**
2010														**19%**	**56%**	**78%**	**98%**	**99%**	**100%**	**100%**	**100%**
	ARMD													16%	44%	70%	98%	99%	100%	100%	100%
	CAS													18%	53%	77%	100%	100%	100%	100%	100%
	CECR (Construction & ECR)													0%	15%	50%	75%	90%	95%	98%	100%
	EDUC													5%	14%	35%	85%	99%	100%	100%	100%
	ESMD													21%	55%	75%	99%	100%	100%	100%	100%
	SMD													16%	56%	76%	98%	99%	99%	100%	100%
	SOMD													22%	64%	85%	99%	100%	100%	100%	100%
	OIG													18%	39%	70%	100%	100%	100%	100%	100%
2011																		**19%**	**44%**	**72%**	**95%**
	ARMD																	15%	35%	60%	90%
	CAS																	20%	45%	75%	98%
	CECR (Construction & ECR)																	5%	20%	50%	75%
	EDUC																	10%	20%	40%	85%
	ESMD																	20%	40%	65%	90%
	SMD																	20%	45%	75%	98%
	SOMD																	20%	50%	80%	97%
	OIG																	25%	50%	75%	100%

Note: Actuals through Mar-2010; projections after that

FTE information

For each reference to FTE data below, please provide numbers and cost information for rotators (IPAs, etc.) separately from permanent employees and provide information as to how many FTEs are for permanent part time vs. full time vs. non-permanent full and part time. Please provide information for JPL, including fully burdened personnel costs.

Answer: Although we can currently show the FTE level programmatically (by Mission Directorate and Science Theme, not by Center or Organization within a Center), in the past we were only able to count our workforce by Organization. The data included below shows FTE by Center and Program beginning in FY 2005 and, in a separate chart, FTE by employee type. You will notice that over 90 percent of our workforce is Full-Time Permanent employees.

IPA information:

Number of Employees

	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	Total
ARC	0	1	2	5	3	0	11
DFRC	2	1	1	0	0	0	4
GRC	1	1	1		1	1	5
GSFC	1	3	3	2	1	1	11
HQ	4	3	1	2	3	4	17
JSC	1	6	2	4	3	2	18
KSC	0	0	0	0	0	0	0
LaRC	2	1	4	1	1	1	10
MSFC	0	2	1	5	3	2	13
SSC	0	0	0	0	0	0	0
Totals	11	18	15	19	15	11	89

Cost perdiem*	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	Total
ARC				65	130		195
DFRC	65	65	65				195
GRC	65	65	65				195
GSFC	65	195	130	65	65	65	585
HQ	130	130	65	65	65	130	585
JSC	65	195	65	65	65	65	520
KSC							0
LaRC	130	65	130		65		390
MSFC		65					65
SSC							0
Total	520	780	520	260	390	260	2730

* $K, used 65K as avg

73. What are the end-of-year FTE data for each of the last five fiscal years for each center and for headquarters and how does this break out by mission directorate with science separated into the four science divisions/programs?

Answer: The end-of-year FTE data for each of the last five fiscal years are shown in the following chart:

Mission Directorate:

		FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
ARC	Aeronautics Research	254.0	239.0	260.0	266.0	236.0	235.0
	Cross-Agency Supt	542.0	522.0	561.0	537.0	612.0	613.0
	Education	1.0	3.0	4.0	3.0	2.0	2.0
	Exploration Systems	253.0	284.0	266.0	226.0	197.0	198.0
	Science	167.0	151.0	165.0	191.0	166.0	166.0
	Space Operations	23.0	20.0	18.0	31.0	20.0	20.0
	Total	**1240.0**	**1219.0**	**1274.0**	**1254.0**	**1233.0**	**1234.0**
DFRC	Aeronautics Research	212.0	176.0	171.0	147.0	137.0	137.0
	Cross-Agency Supt	200.0	201.0	207.0	225.0	238.0	239.0
	Education	3.0	3.0	4.0	3.0	3.0	3.0
	Exploration Systems	35.0	48.0	74.0	71.0	57.0	58.0
	Science	22.0	84.0	93.0	103.0	112.0	112.0
	Space Operations	5.0	5.0	6.0	7.0	6.0	6.0
	Total	**477.0**	**517.0**	**555.0**	**556.0**	**553.0**	**555.0**
GRC	Aeronautics Research	465.0	419.0	423.0	414.5	418.0	419.0
	Cross-Agency Supt	688.0	645.0	634.0	624.3	654.0	655.0
	Education	4.0	5.0	7.0	7.7	6.0	6.0
	Exploration Systems	423.0	460.0	462.0	425.6	396.0	396.0
	Science	39.0	42.0	47.0	53.0	75.0	75.0
	Space Operations	48.0	55.0	64.0	81.8	110.0	111.0
	Total	**1667.0**	**1626.0**	**1637.0**	**1606.9**	**1659.0**	**1662.0**
GSFC	Aeronautics Research	1.0	3.0	4.0	0.0	0.0	0.0
	Cross-Agency Supt	1741.0	1653.0	1594.0	1585.0	1705.0	1711.0
	Education	3.0	3.0	3.0	3.0	4.0	4.0
	Exploration Systems	181.0	211.0	179.0	109.0	51.0	51.0
	Science	1272.0	1215.0	1221.0	1270.0	1348.0	1351.0
	Space Operations	86.0	101.0	123.0	163.0	155.0	155.0
	Total	**3284.0**	**3186.0**	**3124.0**	**3130.0**	**3263.0**	**3272.0**

JSC	Aeronautics Research	0.0	0.0	0.0	0.0	0.0	0.0
	Cross-Agency Supt	963.0	958.0	859.0	889.0	898.0	899.0
	Education	3.0	4.0	4.0	2.0	2.0	2.0
	Exploration Systems	528.0	749.0	824.0	876.0	862.0	862.0
	Science	25.0	25.0	25.0	22.0	26.0	26.0
	Space Operations	1716.0	1568.0	1596.0	1553.0	1548.0	1549.0
	Total	**3235.0**	**3304.0**	**3308.0**	**3342.0**	**3336.0**	**3338.0**
KSC	Aeronautics Research	0.0	0.0	0.0	0.0	0.0	0.0
	Cross-Agency Supt	967.0	831.0	831.0	803.0	829.0	830.0
	Education	5.0	6.0	7.0	6.0	6.0	6.0
	Exploration Systems	224.0	315.0	449.0	491.0	473.0	474.0
	Science	6.0	6.0	8.0	7.0	2.0	2.0
	Space Operations	864.0	944.0	906.0	824.0	843.0	844.0
	Total	**2066.0**	**2102.0**	**2201.0**	**2131.0**	**2153.0**	**2156.0**
LaRC	Aeronautics Research	579.0	549.0	568.0	561.0	590.0	591.0
	Cross-Agency Supt	944.0	851.0	798.0	807.0	853.0	854.0
	Education	11.0	6.0	6.0	8.0	7.0	8.0
	Exploration Systems	241.0	374.0	410.0	379.0	351.0	349.0
	Science	116.0	110.0	114.0	124.0	130.0	130.0
	Space Operations	43.0	29.0	15.0	16.0	14.0	14.0
	Total	**1934.0**	**1919.0**	**1911.0**	**1895.0**	**1945.0**	**1946.0**
MSFC	Aeronautics Research	0.0	0.0	0.0	0.0	0.0	0.0
	Cross-Agency Supt	995.0	1088.0	1001.0	1009.0	1032.0	1033.0
	Education	6.0	7.0	7.0	6.0	5.0	5.0
	Exploration Systems	773.0	804.0	912.0	976.0	944.0	944.0
	Science	149.0	124.0	127.0	100.0	111.0	111.0
	Space Operations	604.0	504.0	518.0	518.0	474.0	474.0
	Total	**2527.0**	**2527.0**	**2565.0**	**2609.0**	**2566.0**	**2567.0**
SSC	Aeronautics Research	0.0	0.0	0.0	0.0	0.0	0.0
	Cross-Agency Supt	133.0	137.0	134.0	154.0	165.0	165.0
	Education	6.0	5.0	4.0	4.0	3.0	3.0
	Exploration Systems	24.0	34.0	47.0	42.0	38.0	38.0

	Science	18.0	11.0	7.0	8.0	7.0	7.0
	Space Operations	88.0	82.0	76.0	61.0	62.0	63.0
	Total	**269.0**	**269.0**	**268.0**	**269.0**	**275.0**	**276.0**
HQ	Cross-Agency Supt	**1318.0**	**1239.0**	**1193.0**	**1178.0**	**1225.0**	**1225.0**
NSSC	Cross-Agency Supt	**64.0**	**105.0**	**123.0**	**128.0**	**146.0**	**146.0**
NASA	Aeronautics Research	1511.0	1386.0	1426.0	1388.5	1381.0	1382.0
	Cross-Agency Supt	8555.0	8230.0	7935.0	7939.3	8357.0	8370.0
	Education	42.0	42.0	46.0	42.7	38.0	39.0
	Exploration Systems	2682.0	3279.0	3623.0	3595.6	3369.0	3370.0
	Science	1814.0	1768.0	1807.0	1878.0	1977.0	1980.0
	Space Operations	3477.0	3308.0	3322.0	3254.8	3232.0	3236.0
	Total	**18081.0**	**18013.0**	**18159.0**	**18098.9**	**18354.0**	**18377.0**

* Straight Line Projection at the rate Through February

** Projection using the same rate per Mission as FY 2010

*** Projection using the same rate per Mission as FY 2010

Science Themes

		FY 2006	FY 2007	FY 2008	FY 2009	FY 2010 *	FY 2011
ARC	Earth Science System	66.0	60.0	58.0	63.0	49.0	49.0
	Planetary Science	37.0	38.0	53.0	61.0	62.0	62.0
	Astrophysics	63.0	52.0	52.0	61.0	49.0	49.0
	Heliophysics	1.0	1.0	2.0	6.0	6.0	6.0
	Subtotal	167.0	151.0	165.0	191.0	166.0	166.0
DFRC	Earth Science System	16.0	38.0	39.0	39.0	42.0	42.0
	Planetary Science	1.0	1.0	0.0	1.0	0.0	0.0
	Astrophysics	5.0	45.0	54.0	63.0	70.0	70.0
	Heliophysics	0.0	0.0	0.0	0.0	0.0	0.0
	Subtotal	22.0	84.0	93.0	103.0	112.0	112.0
GRC	Earth Science System	2.0	2.0	2.0	1.0	2.0	2.0
	Planetary Science	37.0	39.0	44.0	51.0	71.0	71.0
	Astrophysics	0.0	1.0	0.0	0.0	0.0	0.0
	Heliophysics	0.0	0.0	1.0	1.0	2.0	2.0
	Subtotal	39.0	42.0	47.0	53.0	75.0	75.0
GSFC	Earth Science System	506.0	459.0	479.0	587.0	610.0	613.0

	Planetary Science	49.0	79.0	69.0	70.0	95.0	95.0
	Astrophysics	377.0	370.0	384.0	353.0	338.0	338.0
	Heliophysics	340.0	307.0	289.0	260.0	305.0	305.0
	Subtotal	1272.0	1215.0	1221.0	1270.0	1348.0	1351.0
JSC	Earth Science System	0.0	1.0	3.0	0.0	6.0	6.0
	Planetary Science	25.0	19.0	19.0	18.0	15.0	15.0
	Astrophysics	0.0	5.0	3.0	4.0	5.0	5.0
	Heliophysics	0.0	0.0	0.0	0.0	0.0	0.0
	Subtotal	25.0	25.0	25.0	22.0	26.0	26.0
KSC	Earth Science System	3.0	5.0	6.0	4.0	0.0	0.0
	Planetary Science	3.0	1.0	1.0	0.0	2.0	2.0
	Astrophysics	0.0	0.0	0.0	3.0	0.0	0.0
	Heliophysics	0.0	0.0	1.0	0.0	0.0	0.0
	Subtotal	6.0	6.0	8.0	7.0	2.0	2.0
LaRC	Earth Science System	90.0	86.0	91.0	105.0	109.0	109.0
	Planetary Science	24.0	20.0	17.0	13.0	14.0	14.0
	Astrophysics	0.0	0.0	0.0	0.0	1.0	1.0
	Heliophysics	2.0	4.0	6.0	6.0	6.0	6.0
	Subtotal	116.0	110.0	114.0	124.0	130.0	130.0
MSFC	Earth Science System	30.0	26.0	30.0	20.0	20.0	20.0
	Planetary Science	50.0	26.0	28.0	29.0	41.0	41.0
	Astrophysics	52.0	51.0	51.0	41.0	40.0	40.0
	Heliophysics	17.0	21.0	18.0	10.0	10.0	10.0
	Subtotal	149.0	124.0	127.0	100.0	111.0	111.0
SSC	Earth Science System	18.0	11.0	7.0	8.0	7.0	7.0
	Planetary Science	0.0	0.0	0.0	0.0	0.0	0.0
	Astrophysics	0.0	0.0	0.0	0.0	0.0	0.0
	Heliophysics	0.0	0.0	0.0	0.0	0.0	0.0
	Subtotal	18.0	11.0	7.0	8.0	7.0	7.0
HQ	Science Mgmt, Policy and Admin	78.0	50.0	48.0	44.0	45.0	45.0
	NASA Mgmt Office	17.0	0.0	0.0	0.0	0.0	0.0
	Earth Science Div	37.0	39.0	36.0	35.0	38.0	38.0
	Planetry Science Div	22.0	22.0	27.0	26.0	28.0	28.0
	Astrophysics Div	18.0	17.0	17.0	16.0	18.0	18.0
	Heliophysics Div	6.0	17.0	17.0	17.0	17.0	17.0
	Subtotal	178.0	145.0	145.0	138.0	146.0	146.0

* In FY 2010, approximately 265 FTE representing the administrative staff supporting the Science Mission at Centers, will be charging to CMO per direction from the FY 2010 Conference Report.

NASA	Science Mgmt, Policy and Admin	78	50	48	44	45	45
	NASA Mgmt Office	17	0	0	0	0	0
	Earth Science Div	768	727	751	862	885	886
	Planetry Science Div	248	245	258	269	326	328
	Astrophysics Div	515	541	561	541	521	521
	Heliophysics Div	366	350	334	300	346	346
TOTAL		**1992**	**1913**	**1952**	**2016**	**2123**	**2126**
Sub-total without HQ**		**1814**	**1768**	**1807**	**1878**	**1977**	**1980**

** The Subtotal without HQ matches the Science Mission Directorate programmatic total shown on the NASA FTE by Mission Chart.

74. For fiscal year 2010, what are the current on-board FTE levels and the end of year (EOY) planned levels, and for fiscal year 2011, what are the anticipated EOY proposed FTE levels.

Answer: Current and Planned FTE Levels

	Current Onboard (as of March 27, 2010)	Planned - FY 2010	Planned – FY 2011
ARC	1238	1233	1234
DFRC	540	553	555
GRC	1631	1659	1662
GSFC	3203	3263	3272
JSC	3311	3336	3338
KSC	2183	2153	2156
LaRC	1904	1945	1946
MSFC	2551	2566	2567
SSC	270	275	276
NSSC	131	146	146
HQ	1200	1225	1225
Total	18162	18354	18377
IG	195	213	213
Total (including IG)	0	0	0

75. What positions were filled by political appointees at the end of each of the past five fiscal years?

Answer: The following chart shows the Position Title of our various political appointees and the year that each position was filled with a new employee.

	FY2005	FY2006	FY2007	FY2008	FY2009
ADMINISTRATOR	X				X
ASSOC DEP ADMIN'TOR POL/PLANS		X			
ASST ADMIN LEG INTERGOV AFFAIRS	X		X		X
CHIEF FINANCIAL OFFICER			X		
CHIEF OF STAFF		X			X
CHIEF STRATEGIC COMMUNICATIONS	X		X		
CONGRESSIONAL RELATIONS SPECIALIST	X	X		X	
DEPUTY ADMINISTRATOR		X			X
DEPUTY AST. ADMIN FOR STRAT & PLANS				X	
DIR, OUTREACH & INTERGOV AFFAIRS		X		X	X
DIRECTOR, STRATEGIC INVESTMENT DIV.I		X			
EDITOR		X			
EXECUTIVE ASSISTANT	X	X	X		
LEGISLATIVE AFFAIRS SPECIALIST			X		
MINI-RF TECH DEVELOP & INTEG ANALYST				X	
PROGRAM SPECIALIST	X	X			
PUBLIC AFFARIS SPECIALIST		X			
SENIOR ADVISOR	X		X		
SPECIAL ASSISTANT	X			X	X
SR ADVISOR TO ADMINISTRATOR	X				
STAFF SUPPORT SPECIALIST	X				
STRATEGIC COMM SPECIALIST	X				
WHITE HOUSE LIAISON		X	X		X

76. What positions are currently filled by political appointees and what positions are projected to be filled by political appointees in fiscal year 2011?

Answer: Our current budget plan accounts for 15 total political appointee for FY 2010 and FY 2011 at our Headquarters building. The following chart shows the breakdown of the 15 FTE for each year.

	FY 2010	FY 2011
Office of the Administrator	6	6
Office of the Chief Financial Officer	1	1
Office of Communications	3	3
Office of Legislative and Intergovernmental Affairs	4	4
Office of the General Counsel	1	1
TOTAL	15	15

77. What are the average annual costs of a fully-loaded FTE in fiscal years 2010 and 2011?

Answer: The fully loaded rate for an employee in FY2010 is about $146,000. The rate for FY2011 is about $151,000.

Representative Adam Schiff
Questions for the Record

1. **Administrator Bolden, you mentioned the budget's inclusion of efforts to develop and build a heavy lift vehicle. Can we build a heavy lift vehicle for cheaper than the Ares V, which is based on Shuttle technology and for which work has already begun? In this hearing, we heard that the price of heavy lift could be from $30-50 billion. How can we reduce that price? Would reducing capability, as compared to the Ares V, reduce costs significantly?**

   Answer: The Nation needs to aggressively bring about an affordable launch capability if humans are to explore destinations beyond low earth orbit in the 2020-2025 timeframe. A heavy lift vehicle is not only required for NASA's exploration strategy, but also serves commercial and national security needs as well as keeping the U.S. industrial base competitive in a global market.

   The FY 2011 budget request introduces a new Heavy-Lift Research and Development (R&D) Program that will focus on developing game-changing technologies to help reduce cost overall by improving our space launch propulsion technologies. This effort will include development of a U.S. first-stage hydrocarbon engine for potential use in future heavy lift (and other) launch systems, as well as basic research in areas such as new propellants, advanced propulsion materials manufacturing techniques, combustion processes, and engine health monitoring. Additionally, NASA will initiate development and in-space testing of in-space engines. Areas of focus could include a liquid oxygen/methane engine and potentially also low-cost liquid oxygen/liquid hydrogen engines. This work will build from NASA's recent R&D experience in this area, and the test articles will be viewed as a potential prototype for a subsequent operational engine that would be restartable and capable of high acceleration and reliability. These technologies will increase our heavy-lift and other space propulsion capabilities and significantly lower operations costs – with the clear goal of taking us farther and faster into space consistent with safety and mission success criteria. In support of this initiative, NASA will explore cooperative efforts with the Department of Defense and also develop a competitive process for allocating a small portion of these funds to universities and other non-governmental organizations. This research effort along with many of our new technology initiatives will be coordinated with the broader Agency technology initiative led by NASA's new Chief Technologist.

   It is important to understand that reducing capability, as in utilizing a smaller launch vehicle, does not always equate to a cheaper price, especially when significant lift capabilities are needed for a long-duration mission such as to Mars. In fact, it can be more expensive from an operational perspective if it takes more launches to lift the same amount of mass that a larger launch vehicle could lift with fewer trips. This conundrum is why it is so critical for NASA to develop game-changing exploration technologies that are lighter and leaner, thus requiring fewer launches. At the same time, NASA also needs to focus on developing new launch propulsion technologies that exceed today's capabilities, thus shortening the time it will take to reach destinations like Mars – capabilities that NASA will develop based on the FY 2011 budget request.

With regard to cost estimates for heavy-lift, it is difficult to provide an accurate estimate given that this estimate would depend on type of vehicle chosen and its capabilities, among many other things. Such an estimate also would depend greatly on the phasing of funds available. However, NASA believes that cost savings could be realized by developing a heavy-lift vehicle that could be used by multiple users (EELV, commercial, other Government agencies.) As such, multiple users of the same vehicle would likely lower the overall lifecycle cost through higher production rates.

With regard to the $30B to $50B figure cited at the hearing, NASA would like to clarify that those numbers are most closely related to the Ares V project and are rough cost estimate, based on varying assumptions. Based on preliminary Agency estimates, NASA anticipates that the Ares V project costs, through 2020, including development and early production, would be $27B – similar to the $30B ballpark figure cited at hearing. The $50B estimate cited is comparable to Ares V costs, including development and early production through 2025. (Note: Ares I and V share some development and fixed costs such as shared hardware, which must be considered in any estimate for one vehicle without the other. Therefore, if Ares I were continued, Ares V project costs through 2020 including development and early production would be around $16.5 billion.) However, none of the aforementioned estimates include any of the many supporting elements required for launch, such as ground facilities, mission control, and program integration, or any payload. Those costs would be additional.

Ranking Member Frank R. Wolf
Questions for the Record

Space Exploration

1. **The Augustine report outlined five options. Your plan is different than any of his options, but sounds most like his "option 2": extend ISS to 2020; investments in technology development and commercial transport to low-earth orbit; funds for enhanced usage of the ISS; all under current budget constraints. Augustine's option 2 would not deliver heavy-lift capability until the late 2020's and does not have funds to develop the systems needed to land on or explore the Moon in the next two decades. Under the President's proposal, when would a heavy-lift capability be delivered and when would we have the capability to land on or explore the moon?**

 Answer: The President's approach is closest to Option 5B in the Augustine report. Norm Augustine stated at the April 15 Florida space conference that, "You will recognize the President's program as being very close to the Option 5B that we had proposed. It would seem that if adequately funded, and if timely decisions are made, the President's program does give us a way to have a human space flight program worthy of a great nation and, as others have said, to transform us from transportation to exploration."

 On April 15, 2010, the President laid out the goals and strategies related to the FY 2011 budget request for human exploration of our solar system, including a sequence of deep-space destinations matched to growing capabilities, progressing step-by-step until we are able to reach Mars. In addition to investing in transformative heavy-lift technologies, the President called on NASA to select a rocket design no later than 2015 and then begin to build it. A decision no later than 2015 means that major work on building a new heavy-lift rocket will likely begin two years sooner than it was previously planned to begin.

 The FY 2011 budget request introduces a new Heavy-Lift Research and Development (R&D) Program that will focus on developing game-changing technologies to help reduce cost overall by improving our space launch propulsion technologies. This effort will include development of a U.S. first-stage hydrocarbon engine for potential use in future heavy-lift (and other) launch systems, as well as basic research in areas such as new propellants, advanced propulsion materials manufacturing techniques, combustion processes, and engine health monitoring. Additionally, NASA will initiate development and in-space testing of in-space engines. Areas of focus could include a liquid oxygen/methane engine and potentially also low-cost liquid oxygen/liquid hydrogen engines. This work will build upon NASA's recent R&D experience in this area, and the test articles will be viewed as a potential prototype for a subsequent operational engine that would be re-startable and capable of high acceleration and reliability. These technologies will increase our heavy-lift and other space propulsion capabilities and significantly lower operations costs – with the clear goal of taking us farther and faster into space, consistent with safety and mission success criteria. In support of this initiative, NASA will explore cooperative efforts with the Department of Defense and also develop a competitive process for allocating a small portion of these funds to universities and other non-governmental organizations. This research effort, along with many of our new technology initiatives, will be coordinated with the broader Agency technology initiative led by NASA's new Chief Technologist.

Under the FY 2011 budget request, NASA also plans to send precursor robotic missions to candidate destinations such as the Moon, thus paving the way for later human exploration of the Moon, Mars and its moons, and nearby asteroids. Like the highly successful Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (LCROSS) missions that captured the Nation's attention last fall, future exploration precursor missions will scout locations, gather key knowledge and demonstrate technologies to identify the most compelling and accessible places to explore with humans and validate potential approaches to get them there and back safely. These missions will provide vital information—from soil chemistry to radiation dose levels to landing site scouting to resource identification—necessary to plan, design and operate future human missions. These missions will help us determine the next step for crews beyond LEO, answering such questions as: Is a particular asteroid a viable target for crewed mission? Do the resources at the lunar poles have the potential for crew utilization? Is Mars dust toxic? NASA plans to begin funding at least two dedicated precursor missions in FY 2011, and to identify potential future missions to begin in FY 2012 and/or 2013.

Additionally, a new portfolio of explorer scouts will execute small, rapid turn-around, highly competitive missions to exploration destinations. Generally budgeted at between $100-200M lifecycle cost, these missions will allow NASA to test new and innovative ways of doing robotic exploration of destinations of interest to future human exploration. Selected projects may provide multiple small scouting spacecraft to investigate multiple possible landing sites, or provide means of rapid-prototyping new spacecraft approaches.

2. **Augustine's report said "no plan compatible with the FY 2010 budget profile permits human exploration to continue in any meaningful way." And that a budget rising to about $3B above the FY 2010 budget profile could support a "viable" program. This budget does not have the additional funds that Augustine prescribed. What makes a space exploration plan "viable"? Is the plan in the budget "viable" and do you disagree with this finding of the Augustine panel? If so, why?**

Answer: NASA's budget in the President's request does actually rise from $18.7 billion in 2010 to $21 billion in 2015, an increase of about $2.3 billion in annual budget. The FY 2011 budget request for Exploration is $4,263.4 million, an increase of $483.6 million above the FY 2010 enacted level. Included in this budget request is funding for three new, robust programs that will expand the capabilities of future space explorers far beyond those we have today. NASA will embark on these transformative initiatives by partnering with the best in industry, academia and other government agencies, as well as with our international partners. These partners have been integral to much of NASA's previous success and are vital to our bold new vision.

What the FY 2011 budget request does is allow the United States to pursue a new viable and sustainable approach to human space exploration through the development and demonstration of transformative technologies and systems capabilities. Decades of underinvestment in technology led us to the situation, noted by the Augustine review, in which a vigorous exploration program seemed unaffordable. By pausing full-scale development for a few years, NASA will be able to invest in the game-changing technologies that will lower the cost and improve the capabilities of future missions beyond the Moon and help us to break out of the situation where development and operations costs for exploration systems precluded significant investment in technologies for long-term exploration.

The Augustine Committee provided a valuable independent review, and NASA thanks them for their hard work.

3. **The Shuttle program is being closed down at the end of this year. NASA was already faced with the difficult task of transitioning the Shuttle workforce into the Constellation programs. Now you are proposing to terminate the Constellation program at the same time. What do you anticipate as the impacts of this decision on the workforce, both civil service and contractors? How many jobs will be lost, and when? And what measures do you plan to take to minimize the impact of job losses, and the negative impact on the Nation's space industrial base?**

   Answer: The President's strategy and accompanying funding increase in the FY 2011 budget proposal means more jobs for the country, more astronaut time in space, and more investments in innovation. It will result in a longer operating lifetime for the International Space Station, new launch capabilities becoming available sooner, and a fundamentally more ambitious space strategy to take us to an increased number of destinations and to new frontiers in space.

   NASA recognizes that the cancellation of the Constellation Program will personally affect thousands of NASA civil servants and contractors who have worked countless hours, often under difficult circumstances, to make the

Constellation Program successful. NASA appreciates and commends the dedication and sacrifice that these skilled Americans have made in our Nation's human spaceflight program. Civil servants who support Constellation should feel secure that NASA has exciting and meaningful work for them to accomplish after Constellation, and our contractor colleagues should know that NASA is working expeditiously to offer new opportunities for them to partner with the Agency on our new Exploration and Space Operations portfolios. We are also working to mitigate any economic impacts on the affected areas. For example, on April 15, 2010, the President announced a $40M initiative to spur regional economic activity and new jobs for Florida's Space Coast.

At present, NASA is assessing the workforce implications of the FY 2011 budget request. While more precise workforce projections are not likely to be available before the submission of the FY 2012 NASA budget request, the Agency believes it will be able to support delivery of the next *Workforce Transition Strategy* update – with updated, Center-specific numbers for the Space Shuttle and Constellation programs and parametric estimates for new work – by this August. In May, the Agency plans to deliver an update on its workforce transition efforts that will focus on employee assistance and related activities. While the May update will not include workforce projections, it will reflect the significant transition activity that has occurred since the July 2009 edition of the *Workforce Transition Strategy*, and will set the stage for the August edition of that report. The Agency is using the current budget planning activities to develop the details, but an implementation plan and coordinated communications with responsible NASA offices and current Constellation contractors are required to further refine this estimate, which is consistent with past planning experience and cost estimation for the Space Shuttle Transition and Retirement.

With regard to the industrial base, please see NASA's response to Question 4.

4. Was the decision to scrap Constellation fully considered from a national security perspective? Was the National Security Council part of the decision-making process?

Answer: NASA cannot discuss budget formulation discussions within the Administration. However, NASA would like to emphasize that our Nation's space partners communicate frequently with regard to the Federal government space enterprise.

NASA will continue to work closely with our other Federal government partners, including the Department of Defense and the National Reconnaissance Office as planning for FY 2011 implementation moves forward. For example, discussions are underway at all levels to ensure that we carefully consider and maintain the space industrial base, particularly with regard to NASA's discontinued use of solid rocket fuel and motors following the transition away from Constellation. Several recent studies in this area, coupled with current dialogue in the Federal government's Solid Rocket Motor Industrial Base Interagency Task Force and several other joint forums, also address this important area and NASA will continue to work to resolve any integrated issues in these joint forums at all levels.

5. **In light of the widespread opposition, on March 11, I and several other Members wrote to you asking you to assemble a team of NASA experts to conduct a 30-day review of the new proposal, test it for "ground-truth", and suggest possible alternatives and modifications within the current proposed budget. Will you conduct such a review?**

   Answer: The Administrator responded to the March 11, 2010, letter signed by Congressman Wolf and other Members by letter dated April 7, 2010, a copy of which follows:

National Aeronautics and Space Administration
Office of the Administrator
Washington, DC 20546-0001

April 7, 2010

The Honorable Frank Wolf
U.S. House of Representatives
Washington, DC 20515

Dear Congressman Wolf:

Thank you for your letter of March 11, 2010, signed jointly with other Members of Congress, requesting that NASA use a team of experts from three key NASA human spaceflight Centers to review how exploration spacecraft and launch vehicle development and testing is maintained under the President's FY 2011 budget proposal. Your letter also expressed interest in ensuring uninterrupted, independent U.S. human spaceflight access to the International Space Station (ISS) and beyond.

I strongly concur with your assertion that the United States should remain the world's leading space-faring nation, and I am confident that our FY 2011 budget will strengthen that leadership position. I am especially pleased that the President has asked Congress to maintain U.S. leadership and continuous U.S. presence in space by extending the life of the ISS, likely beyond 2020. That extension, dramatic improvements in space exploration technology, and the enhanced use of robotics to expand the reach of our exploration program, will all serve to inspire new generations of young people to look up to the United States as the world's leading space-faring nation. Those same young men and women will be inspired to study science, technology, engineering, and mathematics – and to become our future astronauts, scientists, and engineers.

Our FY 2011 request would allow NASA to build a technological foundation for sustainable, beyond-low-Earth orbit (LEO) human exploration of our Moon, near-Earth asteroids, Lagrange points, and, ultimately, Mars. The journeys to these destinations, which we are likely to reach faster and more affordably under our new vision, will also play a huge role in inspiring youth. I also want to note that the FY 2011 request includes funding to encourage participatory exploration and to enhance our educational programs, along with other investments to support NASA's longstanding educational goals.

The President's plan also provides resources for the Shuttle program to fly out the remainder of the manifest by the end of FY 2010, as planned, and then retire. The FY 2011 budget request also includes funds for the Shuttle to complete the manifest by the end of December 2010, in the event that the final flights cannot be completed by the end of FY 2010. Extending the Shuttle beyond the current manifest would result in a "gap" of 2-3 years between the last manifested flight and any new additional Shuttle flights due to the time it would take to complete production of additional external tanks. In addition, this would divert resources from investments in future heavy lift and propulsion Research and Development (R&D), and space technology needed for more flexible and cost-effective U.S. human exploration beyond LEO in the future.

While I understand the dedication to the Constellation effort, the Augustine Committee found that "the current U.S. human spaceflight program appears to be on an unsustainable trajectory." The Committee also found that, constrained to the FY 2010 budget, "the heavy-lift Ares V is not available until the late 2020s, allowing only orbital flights to the Moon. In addition, there are insufficient funds to develop the lunar lander and lunar surface systems until well into the 2030s, if ever." Continuing Constellation in the expected budget environment would have forced a choice between ISS extension or substantially delaying development of a heavy-lift launch vehicle, and also would have precluded significant R&D investments in breakthrough technologies that can increase the opportunities for (and reduce the cost of) future human missions beyond LEO. The President's new plan will stimulate a U.S. commercial enterprise to ferry crew from the Earth to LEO to support the ISS to eliminate reliance on foreign transport, provide the flexibility to begin work earlier on the heavy-lift launch vehicle that will be needed to get humans out of LEO, and invest in transformative technologies that will enable long-duration missions beyond LEO and ultimately to Mars and other destinations.

Consistent with your suggestion, I am pleased to report that key personnel from the Johnson, Kennedy, and Marshall Space Centers are already actively engaged in continuing to fill in the details of the President's new course for NASA. At my direction, NASA has formed six senior study teams of experts from the Centers and Headquarters to map out the details of the specific proposed human spaceflight investments in the President's FY 2011 request and plan for how the Constellation Program could be closed out in an orderly manner. The six teams are focused on: Constellation Transition; Heavy-Lift and Propulsion Technology; Commercial Crew; Exploration Robotic Precursors; Flagship Technology Demonstrations; and Enabling Technology Development and Demonstration. The teams will assess how to best capture the data, results, and lessons-learned from the Constellation program to help inform the new program and will assess workforce, procurement, and other issues to ensure that people and facilities are best utilized to meet the needs of NASA's new missions. NASA has learned a lot from its work on Constellation, and I want to ensure that we maximize use of that knowledge.

The work of the six teams will form the basis of the detailed plans that we will share with you and other Members about our three new robust exploration programs:

1. Technology Demonstration Program -- $652 million proposed for FY 2011 and $7.8 billion proposed over the next five years;
2. Heavy-Lift and Propulsion Research and Development -- $559 million proposed for FY 2011 and $3.1 billion proposed over the next five years; and,
3. Robotic Precursor Missions -- $125 proposed for FY 2011 and $3 billion proposed over the next five years.

While these teams have been given latitude to determine the details of this bold new budget, I do want you to understand that they will not develop alternatives to the President's vision – or any type of "Plan B." While I hope that much of their work will be complete in the next 30 days, I expect that NASA will continue to refine our plans throughout the coming months. We remain excited about the proposal as presented and look forward to working with Congress to clear up misunderstandings about the FY 2011 request to enable us to find a path forward on areas where disagreements remain.

Your interest and support will be critical as we find a solution to the budget questions that have been raised. I ask you to carefully review our request and to join me in pushing for enactment of this $19 billion investment—the largest NASA budget ever proposed—into the future of the American space program. Thank you for your interest in NASA.

Sincerely,

Charles F. Bolden Jr.
Administrator

Use of Current Year Exploration Funds

6. **At the time the FY 2010 bill was finalized there was uncertainty about what NASA would propose as its new exploration program. As a result, the bill includes language stating that none of the funds "shall be available for the termination or elimination of any program, project or activity of the architecture for the Constellation program nor shall such funds be available to create or initiate a new program, project or activity, unless such program termination, elimination, creation, or initiation is provided in subsequent appropriations acts." How are you interpreting this language, and how are you preceding on the Constellation programs this year?**

   Answer: Consistent with the provisions of the FY 2010 Consolidated Appropriations Act (P.L, 111-117), NASA is continuing to implement the programs and projects for the architecture of the Constellation Program. All work that is currently under contract for Constellation will continue. However, the Administrator has instructed the Constellation Program to refrain from initiating new work not currently under contract, and also to refrain from expanding the scope of any work that currently is under contract. These decisions are being made based on NASA's obligation to manage the funds in a prudent way for the taxpayer since the likelihood that those procurements will be needed is now diminished.

7. **Will you propose supplemental language in order to gain Congressional approval of your exploration spending plans for the current fiscal year?**

   Answer: NASA does not plan to submit supplemental language for Exploration at this time.

8. **Your budget describes a plan to close out existing Constellation contracts as soon as possible. What actions do you plan to take this year? Do you plan to proceed with the Constellation program work through the end of the year?**

Answer: NASA is continuing to implement the programs and projects for the architecture of the Constellation Program. All work that is currently under contract for Constellation will continue. For example, NASA will complete documentation of the Preliminary Design Review (PDR) this year. NASA believes that completing the Constellation PDR will ensure that historical data from Constellation work is documented, preserved and made accessible to future designers of other next-generation U.S. human spaceflight systems.

With regard to Constellation closeout activities, the FY 2011 budget request provides a total of $2.5B in FY 2011and FY 2012 for Constellation closeout and transition costs – funding that is expected to cover closeout activity associated with facilities, environmental remediation, workforce, and prime and support contracts. However, NASA will not begin to implement those activities until an FY 2011 budget has been approved by Congress.

Following the release of the FY 2011 budget request, NASA established six study teams within Exploration Systems Mission Directorate to ensure we understand the steps (and the implications of those steps) that would need to be taken for an orderly transition of the Constellation Program and to plan for the implementation of the new Exploration program. The work undertaken by these teams is a necessary part of that planning. This is only an evaluation of plans, and no termination action has been directed or taken. The data assembled by the study teams will equip NASA with vital and substantive information that we will need once an FY 2011 budget has been approved by Congress and NASA embarks on its efforts to implement it.

9. **What instructions or direction have been given to Constellation program contractors? Have they been instructed to stop or slow down work? Even if they haven't been instructed to do so, are they taking these actions on their own in light of the President's proposal to terminate?**

Answer: The Administrator has instructed the Constellation Program to refrain from initiating new work not currently under contract, and also to refrain from expanding the scope of any work that currently is under contract. These decisions are being made based on NASA's obligation to manage the funds in a prudent way for the taxpayer since the likelihood that those procurements will be needed is now diminished. NASA has not taken any action that would significantly hamper the ability of the Constellation Program to proceed. While these actions may potentially delay the start of work intended for downstream portions of the Constellation Program, including these potential delays in the program is not a termination.

NASA has not instructed its contractors to stop or slow down work in connection with NASA's planning efforts for the FY 2011 budget request. However, over the last several months, the pace of some contractual work has been affected by FY 2010 appropriations. For example, Exploration Systems operated under a FY 2010 Continuing Resolution (CR) for most of the first three months of FY 2010. This limited NASA's appropriations to the FY 2009 enacted level for almost a full quarter of the year, resulting in a reduction of approximately $200M from the FY 2010 requested level for those first three months. Under the CR, ESMD had sufficient forward funding on its major contract for the Constellation Program to execute at its planned level of activity for that period. When the FY 2010 appropriation was not fully funded at the level of the President's budget request, project managers had to take into consideration the possibility that their projects could run out of funds. As a result, in some cases, the rate of spending has slowed to avoid the possibility of running out of funds.

In summary, any slowdown of work currently under our contracts is related to FY 2010 funding constraints and not the pending FY 2011 budget request.

10. Have contractors already begun to take action to stop work and lay off workers? Do you expect this to happen during the course of this year?

Answer: NASA has not instructed the contractors to stop work. In fact, NASA has consistently reminded its contractors of their legal obligation to continue FY 2010 work, per the terms of their contract.

11. If part, or all, of the Constellation program end up being restored by Congress, can we be assured that the actions you are taking this year will not unnecessarily hamper or delay the continuity of the program?

Answer: As noted above, the Administrator has instructed the Constellation Program to refrain from initiating new work not currently under contract, and also to refrain from expanding the scope of any work that currently is under contract. Pursuant to that instruction, as of mid-April, NASA had canceled five planned procurements, including planned studies. However, NASA has not taken any action that would significantly hamper the ability of the Constellation Program to proceed. While these actions may potentially delay the start of work intended for downstream portions of the Constellation Program, incurring these potential delays in the program is not a termination. These decisions have been based on NASA's obligation to manage the funds in a prudent way for the taxpayer since the likelihood that those procurements will be needed is now diminished.

Constellation Termination Costs

12. Your budget request includes $1.9B in FY 2011 and an additional $600M in FY 2012 for estimated close out costs of Constellation. How did you arrive at this estimate, and what is included in the calculation? Are efforts underway to refine this estimate?

Answer: The FY 2011 budget request transitions the Constellation Program, and in doing so, provides a total of $2.5B in FY 2011and FY 2012 for Constellation closeout and transition costs – funding that is expected to cover closeout activity associated with facilities, environmental remediation, workforce, and prime and support contracts. It should be noted, however, that, at present, the breakdown of costs is not complete. The Agency is using the current budget planning activities to develop the details. An implementation plan and coordinated communications with NASA responsible offices and current Constellation contractors are required to further refine the estimate for Constellation closeout, which is consistent with past planning experience and cost estimation for the Space Shuttle Transition and Retirement. NASA's experience with close-out of the Shuttle program will serve as a useful reference for the complexity of the tasks and the potential associated costs. For example, costs for covering closeout of activities associated with facilities, workforce and prime and support contracts are expected to be covered by the requested funds. However, given the decision to transition the Constellation Program, the transition task now involves the closeout of two programs, thus adding another level of complexity in addition to the differences between a developmental and operational human spaceflight program.

13. Your budget describes "tiger teams" that will assess workforce, procurement and other close out issues over the coming months. What is the timetable for reporting to Congress on the work being done by these teams, particularly the cost analysis?

Answer: Although NASA is continuing Constellation Program activities in FY 2010, at the same time, NASA must plan for all likely budget outcomes so that the Agency is ready to implement any new direction and implement appropriate transition activities. This is consistent with how the Agency plans to implement any pending budget in any given year. Forward preparation and planning work is always necessary, even though a budget has not become law.

Following the release of the FY 2011 budget request, NASA established six study teams within ESMD to ensure we understand the steps (and the implications of those steps) that would need to be taken for an orderly transition of the Constellation Program and to plan for the implementation of the new Exploration program. The work undertaken by these teams is a necessary part of that planning. This is only an evaluation of plans, and no termination action has been directed or taken. The data assembled by the study teams will equip NASA with vital and substantive information that we will need once an FY 2011 budget has been approved by Congress and the new fiscal year begins and once NASA embarks on its efforts to implement the approved FY 2011 budget.

It is expected that teams will complete a majority of their work by the end of the 3rd quarter of FY 2010. As that effort is completed over the next several months, NASA will share our findings with Congress and engage with this Subcommittee on our planned next steps.

After assessing the current Constellation baseline status and developing the action plan for a Constellation transition, and receiving appropriate legislative direction, future implementation and execution of the plan will be transferred to a Constellation Transition and Closeout Project. Existing Agency infrastructure will be utilized to the maximum extent possible to codify decisions and conduct reviews, analysis, and integration of transition activities and plans, such as: the Exploration Systems Mission Directorate Program Management Council; the Agency Program Management Council; the Center Management Council; the Constellation Control Board; the Systems Engineering and Integration Control Board; the Budget Rollout Integration Team; and the Transition Control Board.

Plutonium 238

14. I understand that the FY 2011 budget includes funding to restart Plutonium 238 production. Can you describe the need for this, how much money is in the FY 2011 budget, whether other alternatives exist, and what the plan is for restarting production?

Answer: It is imperative that the funding requested in the President's FY 2011 budget request for restarting domestic production of Pu-238 be approved by Congress. Specifically, $30M is included in the President's request, evenly divided with $15M in the DOE's budget request, and $15M in NASA's budget request. It is planned that DOE and NASA will share in the capital cost of reestablishing a domestic production capability. Although NASA is expected to be a primary user of Pu-238 produced in the near future, this capability will also be available to support future national security applications, if needed. DOE's share in the capital costs is consistent with the Department's mission to maintain a national capability for a range of potential Federal users.

A new Pu-238 production capability is required to maintain Radioisotope Power Systems as an important national capability. Because of dwindling stockpile of existing Pu-238, and the long lead-time associated with reestablishing a domestic production capability (as much as 6-8 years), DOE is working, in coordination with user agencies, to reestablish Pu-238 production at a rate sufficient to support both NASA and national security missions. NASA routinely provides to DOE updates on our requirements for Pu-238. Based upon these requirements, we believe that a production rate of 1-2 kg per year is sufficient for the foreseeable future. This rate can be accomplished using known technology and existing National Laboratory capabilities to produce and separate Pu-238.

This approach minimizes the necessary startup investment, and provides the most rapid initial production of Pu-238, which is necessary to meet NASA's mission requirements. This approach would also limit long-term operating expenses to right-sized facilities and processes. DOE and NASA are preparing a restart plan that will provide additional details. We expect to provide that restart plan to the Subcommittee in the near future.

DOE and NASA are also working together to ensure needed purchases from Russia are completed to ensure an adequate supply of Pu-238 to avoid delaying high-priority missions, including the future major Outer Planets mission NASA is conducting technology studies to support. This additional plutonium is necessary to retire any mission risk due to the schedule of re-establishing U.S. production capability in meeting mission requirements. There are no other alternatives appropriate for our application other than purchase from Russia or restarting domestic production.

NASA has proposed FY 2011 appropriations language that expressly directs NASA to partially fund restart of DOE production infrastructure and direct all the necessary NASA to DOE funds transfers. The inclusion of this legislative language would avoid inadvertently creating additional National Environmental Protection Act (NEPA) review requirements and/or litigation risk by requiring a discretionary NASA funding decision to support this project. Formal arrangements to be established under an existing DOE/NASA memorandum of understanding (MOU) would also need to be consistent with this approach. If approved, NASA will work closely with DOE to ensure that the appropriate steps are taken to ensure a timely restart of domestic Pu-238 production.

15. What specific missions in your FY 2011 budget are dependent upon the development of this capability?

Answer: The production rate and timing for startup of domestic production is governed by projected user demands and the projected depletion of existing supplies of Pu-238. Based on the latest formal NASA guidance on projected mission requirements, the current inventory reserved for space missions is insufficient to support the next four envisioned NASA missions expected within the next decade. Because of the long-lead time involved, establishing a Pu-238 production capability immediately would avoid jeopardizing proposed missions, most of which are beyond the five-year budget horizon covered by the FY 2011 budget request.

Nonetheless, the urgency to restart domestic production of Pu-238 remains extremely high. As noted by the National Research Council, NASA's ability to plan for future missions has already been adversely affected by the uncertainty surrounding long-term supplies of Pu-238. Specifically, envisioned missions that would most directly be affected by a delay in restarting domestic production include the Discovery 12 mission (envisioned for a launch in 2015), a lunar precursor robotic exploration mission (envisioned for launch in 2015), the Mars 2018 mission (envisioned for launch in 2018), and a projected major outer planets mission in the early 2020s.

Education

16. I was surprised to see that your budget request for education is actually a reduction of almost $40M or 21% from the current level. What is the focus of your Education request, and why are you proposing a reduction? What areas of your Education program are being proposed for reduction?

Answer: The FY 2011 budget request of $145.8M for NASA Education is an increase of $19.7M from the FY 2010 budget request. The FY 2010 budget request was $126.1M, with $180.1M enacted and as reflected in the NASA FY 2010 initial Operating Plan.

The FY 2011 budget request of $145.8M reflects the funding required to execute the Agency education plan in FY 2011. This proposed budget does not provide for augmentations to the National Space Grant College and Fellowship Program (Space Grant), Experimental Program to Stimulate Competitive Research (EPSCoR), and NASA Visitor Centers, as appropriated by Congress in recent years.

The nearly $20M increase in the FY 2011 budget request will support the Summer of Innovation project.

This FY 2011 budget request embeds competitive opportunities in NASA Education core operations. In the past three years, Congress has appropriated funds for competitive grants supporting global climate change education, K-12 STEM education, and museum and science center activities. Competitive grants offered by NASA Education in FY 2011 will include:

- Innovations in Higher Education STEM Education, which will offer competitive awards that improve higher education and workforce development;
- Innovations in K-12 STEM Education, providing seed- grants to schools, districts, and non-profit organizations with innovative approaches to improving STEM teaching and learning;
- Global Climate Change Education, which will more actively engage community colleges and minority serving institutions; and,
- NASA Informal Education Opportunities; providing funds to science and museums and planetariums.

The enacted FY 2010 budget included the following Congressional modifications from the original budget request:

+$57.7M, for four Congressionally-directed projects (*Competitive Educational Grants Program; Global Climate Change Education; Science Museums and Planetariums Grants; and NASA Visitor Centers*) and increases two existing projects (*Space Grant and EPSCoR*).

Higher Education STEM Education:

- +$17.2M, Increase Space Grant to $45.6M, as directed
- +$15.0M, Increase EPSCoR to $25.0M, as directed
- +$10.0M, Fund a Global Climate Change Education project, as directed
- -$1.65M, Reduction to Higher Education STEM Education Program

K-12 STEM Education:

- +$15.0M, Fund a K-12 Competitive Educational Grant project (with $10M to be applied to K-12 Summer of Innovation), as directed
- -$4.0M, Reduction to K-12 STEM Education for STEM Student Opportunities
- -$7.9M, Reduction to K-12 STEM Education for Teacher Development

Informal STEM Education

- +$7.0M, Fund a Science Museums and Planetarium Grants project, as directed
- +$7.0M, Fund Education projects at the 10 NASA Visitor Centers, as directed

Cost Overruns in Major Projects

17. It has become common to hear that NASA does not have enough funding to carry out all its missions. One of the contributing factors is the recurring problem of cost and schedule growth in your major projects. GAO now does an annual assessment of your large-scale projects. They reported last month that 9 of the 10 projects they looked at that had been in the implementation phase several years had cost growth ranging from 8 to 68 percent, and launch delays of 8 to 33 months, in the past 3 years. The total cost growth in these projects was $1.2B, or an average of $121M per project. Can you identify what are the factors that are driving this cost growth? Is it lapses in program management, faulty cost estimating, or inadequate contractor oversight?

Answer: Several factors contributed to the cost growth for some of NASA's recent space flight projects. Because NASA projects are one-of-a-kind, potential technical or engineering difficulties are often unknown until the project is well into development. For example, the computer boards for the Glory spacecraft operated flawlessly during testing for more than a year before the project encountered technical difficulties which required a late change to a different computer board. An underestimation of the level of difficulty during project formulation can result in the project cost or schedule at the start of development being underestimated. Other sources of recent cost growth include changes in partner contributions or performance; difficulty manifesting or re-manifesting flights; and changes in the industrial base during development.

18. Whatever the cause, these cost overruns mean that you are able to accomplish less with your funding, and you have to short one project to pay for another. GAO did not make any recommendations, but do you have any initiatives underway that will both improve initial cost estimates, and improve project management to minimize cost and schedule growth?

Answer: The steps that we have taken to standardize our project lifecycle, utilize Standing Review Boards to provide focused assessments at Key Decision Points, the renewed emphasis on tools such as Earned Value Management, the institution of strengthened acquisition planning and monthly reviews, and the use of joint cost and schedule confidence levels in our decision making, have all moved NASA along a path toward improving our delivery of projects on time and within budget. A particularly innovative component of these steps is the January 2009 NASA acquisition strategy policy, which improves NASA's ability to manage performance risk. Among its features, the new policy requires spaceflight and information technology projects and programs to develop joint cost and schedule probabilistic estimates based on identified risk and estimated cost and schedule ranges.

Space Shuttle

19. Your budget request supports the five remaining Shuttle flights before retirement, which is the same program as proposed in last year's budget, but you have asked for an additional $606M to do that compared with last year's request. What has caused the requirement for an additional $606M?

Answer: The FY 2011 budget request includes funding to cover the minimally required workforce and infrastructure needed for safe flight operations through December 2010. The previous budget only covered through the end of FY 2010. The extra funding will provide additional margin to safely fly out the remaining Shuttle manifest, even if doing so slips into fiscal year 2011.

20. What studies and estimates have you done on the costs of extending the Shuttle beyond the five remaining flights in the manifest?

Answer: In April 2009, pursuant to direction in the NASA Authorization Act of 2008 (P.L. 110-422), Section 611(e), NASA examined two bounding cases for an extension of Shuttle operations beyond the current manifest. One case looked at adding three flights to the manifest and spacing out the flights starting with STS-128 to extend operations through FY 2012. The cost estimate for this case required an additional $4.7B above the NASA baseline budget at that time. The second case looked at adding three flights a year through 2015 for a total of 13 additional flights. The cost estimate in for the second case required an additional $14.0B above the NASA baseline budget at that time. We should caution that since the release of that report, NASA has proceeded with the planned shutdown of capabilities no longer needed to support the current, approved Space Shuttle manifest. Therefore, the estimates from last year, which did not include startup costs for vendors that have since been terminated, are no longer valid.

International Space Station

21. Your FY 2011 budget supports the extension of the lifetime of the International Space Station to 2020 or beyond, instead of a phase-out in 2015. How much have you added to the 5 year budget to support this extension?

Answer: Within the five-year horizon of the budget, NASA added $1.2B for life extension, $1.3B to increase ISS functionality, and $800M to enable full utilization of ISS.

22. What scientific or other benefits do we hope to gain from this additional five years of Station activity, and why is that a higher priority than devoting those resources to making the exploration program more viable, in line with the Augustine panel recommendation?

Answer: The ISS Program represents the largest international cooperative endeavor in the history of science and technology, with partners in Canada, Europe, Japan and Russia. It is through this effort that the leading space-faring nations have learned to work together across cultural, political, and technical boundaries, in order to combine resources and achieve objectives that no nation alone could have achieved due to the high costs associated with human and robotic exploration of space. This partnership is the foundation upon which cooperative space exploration missions of the future can be formulated and funded through a global strategic alliance for peaceful purposes. This key national strategic aspect of the ISS partnership was recognized by the National Academy of Sciences Committee on Rationale and Goals of the U.S. Civil Space Program in their 2009 report on the subject, and was re-asserted by the Presidentially-mandated Review of U.S. Human Space Flight Plans Committee in their 2009 report.

In addition, the technological benefits of the ISS have been diverse to date and will continue to grow significantly in the post-assembly phase. During the assembly years, this global team demonstrated the techniques necessary to design, develop, test and evaluate (DDT&E) very large-scale space structures in the hostile environment of low-Earth orbit (LEO). This unprecedented capability has advanced technologies across all distributed systems (e.g., power, thermal, data processing, telecommunications, in-space propulsion, guidance navigation and control, environmental control and life support, etc.) and elements (e.g., materials, structures, robotics, etc.). In the field of environmental control and life support (ECLS) alone, the ISS program has fielded a regenerative system that has pressed the boundaries of environmental technologies and closed the oxygen and water loops to approximately the 75-80 percent recycling level. This work continues with the STS-131 mission that recently delivered an experimental prototype Sabatier reactor to recover waste hydrogen and carbon dioxide and produce water on orbit. This technology will further push the recycling efficiency to approximately 85 percent. In order for humans to explore space, humans must first be able to live in space. These technologies are essential to future missions that will extend human presence beyond LEO.

In the area of scientific research, the ISS Program has finally enabled full-service, continuously operating, crewed laboratories in the space environment. During the challenging assembly years, highly provocative findings have been revealed in the fields of biosciences, material sciences, fundamental physics and polymer chemistry. Unique new phenomena have been experimentally observed in molecular coalescence, gene expression, cell propagation, plant morphology, bio-systemic functionalities and micro-structural properties of inorganic compounds. These observations are indicative of the wealth of scientific knowledge to be gained and the potential for applications as the ISS Science and Technology research program ramps up for the 2011-2020 time period.

In its final report, the Review of U.S. Human Spaceflight Plans Committee (http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf) discussed the role of ISS and its future in the context of the future of U.S. Human Spaceflight (Section 4.2, pp 51-57). The report questions the ceasing of NASA's utilization of the ISS in 2015 based on the amount of time and resources that have been expended on the construction of the facility, and the potential of using it as a scientific testbed and also to advance the exploration goals beyond low Earth orbit.

In its examination of the Scenarios for the Future of the ISS (Section 4.2.3) the committee considered the following three options:

1) End of U.S. participation in the ISS at the end of 2015;
2) Continue ISS operations the present level to 2020; and,
3) Enrich the ISS Program and extend through 2020.

The report implied that executing Scenarios 1 and 2 would lead to a suboptimal utilization of the ISS that would result in a poor return on investment for the U.S. taxpayer and also be a detriment to the international partnerships that grew as a result of research collaborations on the ISS.

In its assessment of Scenario 3, the report states that

> "*Since ISS utilization accounts for a relatively small portion of the planned budget, a significant enrichment of ISS utilization could be achieved with a relatively modest increase in funding.*"

The report also alludes to the fact that the user community has to be reinstated to facilitate the optimal use of the facility.

> "*...the funds originally to be used for research and technology development were reduced. The scientific research community that had hoped to use the ISS has largely been dispersed and will have to be reassembled.*"

In order to determine the research content on the ISS, a great emphasis is placed on implementing the recommendations of the ongoing decadal survey in life and physical sciences to enhance the scientific use of the ISS.

> "*The National Research Council Space Studies Board has recently initiated a decadal survey of life and microgravity science that will identify key scientific issues and strategies for addressing them. This is the first decadal survey in this area, and it will bring the most modern scientific understanding to bear on what questions may be answered in the decade through 2020. An extended, enriched ISS program will enable more of the scientific opportunities identified by the survey to be captured.*"

The path forward is derived on the salient findings of the Review of U.S. Human Spaceflight Plans Committee report which calls for: 1) strengthening the scientific user community in life and physical sciences; 2) using the results of the current NRC Decadal Survey in Life and Physical Sciences to determine the research content; 3) using the ISS as a technology testbed for exploration; and, 4) increasing participation by other government agencies under the aegis of the ISS National Laboratory and working in concert with the international partners using existing agreements.

Representative John A. Culberson
Questions for the Record

Space Exploration

1. **In your testimony before the Commerce, Science, Justice Appropriations Subcommittee, you described your idea of utilizing commercial vehicles as being similar to "leasing" them. Can you please provide additional details about what your idea of "leasing" means? How will it work? What are your cost estimates? Can you provide an example of a current government program that resembles your idea of "leasing"?**

   Answer: Although sometimes used as a general term or analogy, NASA does not lease vehicles. Rather, NASA procures services as a commercial item under the Federal Acquisition Regulations, in accordance with the Commercial Space Act of 1998 (CSA), when cost effective space transportation services that meet specific mission requirements are reasonably available from U.S. commercial providers and are required for NASA missions. In terms of procuring commercial crew services, NASA is still preparing a strategy to support the development of commercial crew transportation services so that the Agency is prepared to proceed if funding is provided in the final FY 2011 budget. Related to this activity, on May 21, NASA released a Request for Information to seek industry feedback to help the Agency plan the overall strategy for the development and demonstration of a commercial crew transportation capability and to receive comments on NASA human-rating technical requirements that have been drafted as part of this initiative. NASA intends to acquire such services in accordance with the CSA once such services are reasonably available.

2. **I understand that innovative technologies are already part of the Orion Crew Exploration Vehicle. In fact, the Augustine Committee included Orion in all five of their options for space exploration. Can you explain the reason behind cancelling a program which is already mature and has applied these technologies into the design from the outset? Is it cost-effective to cancel a program, only to cannibalize a functional design and re-distribute technologies and functions to less mature vehicle concepts?**

   Answer: At the highest level, the President and his staff, as well as NASA senior leadership, closely reviewed the Augustine Committee report, and came to the same conclusion as the Committee: the human spaceflight program was on an unsustainable trajectory. To continue on the previous path we had to decide to either continue the ISS, support a program to get humans beyond LEO, or to make even deeper cuts to other parts of NASA's budget. Further, we would have had insufficient funding to advance the state of the art in any of the technology areas that we need to enable us to do new things in space, such as lowering the cost of access to space and developing close-loop life support, advanced propulsion technology, and radiation protection. The President recognized that what was truly needed for beyond LEO exploration was game-changing technologies; making the fundamental investments that will provide the foundation for the next half-century of American leadership in space exploration. At the same time, under the new plan, NASA would ensure continuous American presence in space on the ISS throughout this entire decade, re-establish a robust and competitive American launch industry, start a major heavy lift technology program years earlier, and build a technological foundation for sustainable beyond-LEO exploration of our moon, near-Earth asteroids, Lagrange points, and ultimately Mars.

Following the release of the FY 2011 budget request, NASA established six study teams within the Exploration Systems Mission Directorate to ensure we understand the steps (and the implications of those steps) that would need to be taken for an orderly transition of the Constellation Program and to plan for the implementation of the new Exploration program. The work undertaken by these teams is a necessary part of that planning. One team, the Constellation Transition team, has initiated a broad survey of current workforce, contracts, facilities, property, security, knowledge capture, information technology, and other Government agency interface issues to determine what infrastructure and hardware could be used by the new programs and projects.

Despite the early nature of these planning efforts, NASA is optimistic that there will be many capabilities developed by the Constellation Program that will feed forward into the new programs. For example, the Orion Capsule is currently pursuing options for autonomous rendezvous and docking and many of the capabilities we are pursuing at a low level through our Exploration Technology Development Program are directly applicable to the new programs. Other important areas that will enable further advancement in the new initiative areas are: advanced robotics, propulsion development and test, autonomous landing and hazard avoidance, and entry, descent, and landing technologies.

Additionally, on April 15, 2010, President Obama laid out the goals and strategies for his new vision for NASA. The President outlined an ambitious effort to foster the development of ground-breaking technologies; increase the number, scope, and pace of manned and unmanned space missions; make human spaceflight safer and more efficient; and help create thousands of jobs. The President directed that NASA proceed to develop a crew rescue vehicle based on the Orion space capsule technology to support crew return requirements on the International Space Station, and providing a technological foundation for systems that can later take us beyond Earth's orbit. We will be able to launch this vehicle within the next few years, creating an American crew escape capability that will increase the safety of our crews on the Space Station, reduce our dependence on foreign providers, and simplify requirements for other commercial crew providers. This effort will also help establish a technological foundation for future exploration spacecraft needed for human missions beyond LEO and will preserve some critical high-tech contractor jobs in Texas, Colorado, and Florida.

3. **Although NASA's messaging has consistently been that the president's FY 2011 budget maintains a robust level of investment in human exploration, the Exploration run-out included in the budget tells a different story. Comparing the FY 2011 budget run-out with the FY 2010 budget run-out, the Exploration account is reduced by nearly $6 billion between FY 2011 and FY 2014. In addition, if you add the $2.5 billion to close out Constellation, then the reduction in expenditures is nearly $8.5 billion. Such drastic cuts exacerbate the problems presented by the Review of U.S. Human Space Flight Plans Committee, and these cuts threaten our human spaceflight program. Please provide the reasoning for these reductions and how they will not endanger America's leadership in human space exploration.**

   Answer: The Exploration Budget increases almost $500 million from FY 2010 to FY 2011, and the requested budget for exploration in FY 2015 is $1.4 billion dollars higher than in FY 2010 – an increase of 37 percent in five years. While the FY 2011 budget request, when compared to the FY 2010 budget reflects less funding for Exploration Systems Mission Directorate, funding for NASA as a whole increases $6B over five years despite a tough budget environment as compared with the FY 2010 budget.

   Although funding for Exploration decreases when compared to the FY 2010 budget runout, funding was increased for other spaceflight priorities that were either critical to enable a safe and effective near-term human space flight program, such as allowing the Shuttle to safely complete its manifest, extending the International Space Station to 2020 and enhancing its utilization; or that were key to supporting human space flight activities in the long-term, such as cross-cutting technology; and developing commercial crew transport capabilities.

   Extending the spatial and temporal boundaries of human spaceflight is an important goal for the Nation and for NASA. However, human spaceflight remains an endeavor with substantial risks, and these risks must be identified, managed and mitigated appropriately to achieve the Nation's goals in space. Thus, as highlighted in the Review of U.S. Human Spaceflight Plans Committee report and as supported by the FY 2011 budget request, investment in a well-designed and adequately funded space technology program is critical to enable progress in exploration. Exploration strategies can proceed more readily and economically if the requisite technology has been developed in advance. That is why the FY 2011 budget request is so critical for NASA.

   The FY 2011 budget request outlines an innovative course for human space exploration, but does not change our goal – extending human presence throughout our solar system. NASA will lead the Nation on this new course of discovery and innovation, providing the technologies, capabilities and infrastructure required for sustainable, affordable human presence in space.

NASA's investment in gaining critical knowledge about future destinations for human exploration, as well as transformational technology development and demonstration will serve as the foundation of NASA's ongoing space exploration effort, broadening opportunities for crewed missions to explore destinations in our solar system that we have not been to before.

Mars is of course a key long-term destination for NASA, and thus we must begin to identify missing capabilities needed for such a mission. Mass is a huge barrier for a Mars mission because higher mass drives up cost, and it slows down progress. More mass without advanced technologies such as advanced propulsion techniques or ways to prevent fuel boil-off in space, means that it will take more trips to lift resources into LEO for Mars missions and substantially more flights required to transport required resources to Mars. The same sort of scenarios also apply to missions for other beyond-LEO missions – more mass without advanced technologies will only serve to drive up costs and extend schedule, pushing our chances of breaking free of LEO even further into the future.

In summary, while a timeline and budget plan for a manned Mars and other beyond-LEO missions is still in work, NASA believes that the benefits of the aforementioned technology development efforts along with anticipated infrastructure efficiencies will lead to sustainable manned missions to beyond-LEO destinations sooner and at less cost than missions currently envisioned under the Constellation Program.

4. **Can you provide additional details on the $2.5 billion budgeted to close down Constellation? Does this figure includes contractors' costs, or is this just NASA's costs? What was this estimate based on?**

Answer: The FY 2011 budget request transitions away from the Constellation Program, and in doing so, provides a total of $2.5B in FY 2011and FY 2012 for Constellation closeout and transition costs – funding that is expected to cover contract termination and closeout activity associated with facilities, environmental remediation, workforce, and prime and support contracts. A portion of this funding will also be used to support the retraining of Shuttle program contractors as that program is brought to a successful close. It should be noted, however, that at present, the breakdown of costs is not complete. The Agency is using the current budget planning activities to develop the details; and an implementation plan and coordinated communications with NASA responsible offices and current Constellation contractors are required to further refine this estimate, which is consistent with past planning experience and cost estimation for the Space Shuttle Transition and Retirement. NASA's experience with close-out of the Shuttle program will serve as a useful reference for the complexity of the tasks and the potential associated costs.

<u>Representative Robert B. Aderholt</u>
Questions for the Record

<u>Space Exploration</u>

1. **My understanding is that if Constellation contracts are terminated, they will be "Terminations For Convenience." Isn't it true that federal agencies <u>almost always</u> cover the costs of contract terminations for TFC's at the agency level, as opposed to from the program funds?**

   Answer: NASA is required to comply with the provisions of the FY 2010 Omnibus Appropriations Act (P.L. 111-117) regarding the Constellation program and, consistent with the Act, NASA has not taken action to terminate any Constellation contract. Consequently, NASA has not made any determination about how to effect any Constellation contract termination. NASA cannot address how other Federal agencies cover the costs of contract terminations.

2. **What letters has NASA sent to any or all of the Constellation Program prime contractors during March 2010? Please provide copies for the record.**

   Clerk's Note: This information was provided by the agency and is retained in the Committee's files.

3. **My understanding is that contract termination costs of the X33 program were borne by the follow-on program: SLI. And that SLI was transitioned into the OSP and NGLT programs. And that when OSP and NGLT were cancelled, the government covered those termination costs. Is that correct?**

   Answer: That is not correct. The X33 was allowed to expire without a formal termination. The Space Launch Initiative (SLI) transitioned to Orbital Space Plane (OSP) and Next Generation Launch technology (NGLT) programs. OSP Phase B contracts were completed. The OSP Phase C/D Request for Proposal (RFP) was cancelled before the RFP was issued. Numerous NGLT contracts were issued and were either completed or were allowed to expire without a formal termination.

4. **To clarify the question about Bill McNally, NASA's head of contracting, it is my understanding that he was in the process of inserting a clause into the Constellation contracts to tell them that NASA would cover contract termination costs, but that he was told by NASA to not do that. Is that correct? Who at NASA, or outside of NASA, told him to not insert that clause?**

   Answer: That is not correct. There was no direction to stop processing this clause in the fall of 2009. In fact, this clause was inserted in the Boeing Avionics and Upper Stage contracts on January 21, 2010, and January 25, 2010, respectively. Upon learning that the President's proposed FY 2011 budget request on February 1, 2010, proposed to cancel the Constellation Program, the Head of Procurement at NASA determined that NASA would not pursue adding this clause to other NASA contracts.

   The activity that was on-going relative to a termination liability clause during this time period was the investigation by NASA personnel as to whether to incorporate into NASA procurement regulations a special termination liability cost clause similar to the one utilized by the Department of Defense. These types of special termination liability cost clauses generally delineate that potential termination liability costs will not be funded on the contract; the identification of funds to cover potential termination costs; and the maximum amount of termination liability under the contract. Incorporation of such a clause into NASA procurement regulations is not imminent.

5. **In the opinion of NASA's Office of Legal Counsel, why is NASA taking actions based on compliance with the Anti-Deficiency Act in spite of bill language in the Omnibus Appropriations Act of 2009 regarding the Constellation Program and report language on the human exploration architecture development? Please provide the written legal opinion.**

   Answer: NASA has neither intended nor attempted to circumvent the restriction in the FY 2010 Consolidated Appropriations Act on terminating Constellation programs, projects, or activities. Instead, NASA's focus has been on ensuring compliance with the strict terms of the provision. The FY 2010 Appropriations Act contained a general appropriation for Exploration activities without specifically addressing the Constellation program. The Appropriations Act then included a provision that there be no termination or elimination of the architecture of Constellation, and no creation or initiation of a new <u>program, project, or activity</u> without further authority. The FY 2010 Appropriations Act provided as follows:

   > "...Provided, That . . . none of the funds provided herein and from prior years that remain available for obligation during fiscal year 2010 shall be available for the termination or elimination of any <u>program, project or activity</u> of the architecture for the Constellation

> program nor shall such funds be available to create or initiate a new program, project or activity, unless such program termination, elimination, creation, or initiation is provided in subsequent appropriations Acts."
>
> Title III, Consolidated Appropriations Act, 2010, Pub. L. No. 111-117, 123 Stat. 3034 (2009).

GAO defines "program, project, or activity" (PPA) as "an element within a budget account." Terms and Definitions, "A Glossary of Terms Used in the Federal Budget Process, GAO-05-734SP Budget Glossary, September 2005. "Program activity" is defined as "[a] specific activity or project as listed in the program and financing schedules of the President's budget." Id.

Thus, based on established usage, the restriction on Constellation termination contained in the 2010 Appropriations Act is limited to termination of a PPA, or an element within the Exploration account. NASA has not terminated any specific contract, although NASA could do so under the restrictive language of the Appropriations Act, which only prohibits termination of any program, project, or activity of the Constellation architecture.

The Antideficiency Act ("ADA") provides in relevant part that no officer of the United States may make or authorize an expenditure or obligation exceeding an amount available in an appropriation, fund, or formal subdivision of funds. 31 U.S. Code §§ 1341(a)(1), 1517. The ADA also requires that an agency ensure it does not contract for work in excess of the appropriations available to fund the work. 31 U.S.C. §§ 1341(a)(1), 1517. Most of the Constellation contracts, including all of the major primes, are incrementally-funded, cost-reimbursement contracts, which are required to have, and do contain, a Limitation of Funds ("LOF") clause to ensure work is performed within the limits of the funding allotted to the contract. The LOF clause (Federal Acquisition Regulation 52.232-22), in paragraph (h), states "the Government is not obligated to reimburse the Contractor for any costs incurred in excess of the total amount allotted by the Government to this contract, whether incurred in the course of the contract or as a result of termination" (emphasis added). Allotted funding therefore includes all costs under the contract, for performance and for any costs resulting from termination.

NASA is acting to comply with both the ADA and the FY 2010 Appropriations Act. The FY 2010 Appropriations Act, prohibiting use of funds for termination of Constellation PPA, does not require that NASA risk an ADA violation, and certainly does not create an exception to the ADA. Reading the FY 2010 Appropriations Act with the ADA, NASA is bound to take steps to ensure that the Constellation contracts are managed according to their existing terms, including the express terms of the Limitation of Funds clause. GAO, Principles of Appropriations Law Vol. II, at 7-48 (2009). As stated previously, NASA has not terminated any Constellation contracts; but NASA has issued letters to two Constellation contractors, reminding the companies of obligations under the LOF clause. This is prudent contract management, intended to avoid coercive deficiencies in violation of the ADA, and should not be interpreted in any other way. Most importantly, it does not terminate any PPA within the Exploration account.

6. **In NASA's opinion, what is an acceptable multi-year cost for developing a heavy-lift capability?**

   Answer: NASA's opinion is that the development of a heavy-lift vehicle must be a component of a program that is sustainable and well-balanced across all of NASA's missions, without relying on the hope of significant future topline budget increases.

   NASA has not established a formal cost estimate for a heavy-lift capability. With regard to cost estimates for heavy-lift, it is difficult to provide an accurate estimate given that this estimate would depend on type of vehicle chosen and its capabilities, among many other things. Such an estimate also would depend greatly on the phasing of funds available. However, the Agency has developed rough, preliminary estimates for project costs – estimates that vary based on which assumptions (i.e. schedule, budget year, shared costs etc.) are included in an estimate.

   Based on preliminary Agency estimates, NASA anticipates that the Ares V project costs through 2020, including development and early production, would be \$27B – similar to the \$30B ballpark figure cited at hearing. The \$50B estimate cited is comparable to Ares V costs, including development and early production through 2025 -- again, if Ares I were cancelled. However, none of the aforementioned estimates include any of the any of the supporting elements required for launch, such as ground facilities, mission control, and program integration, or any payload. Those costs would be additional. (Note: Ares I and V share substantial development and fixed costs such as shared hardware, which must be considered in any estimate for one vehicle without the other. Therefore, if Ares I were continued, Ares V project costs through 2020, including development and early production would be around \$16.5B. However, as the Augustine committee concluded, this direction is unsustainable.

   The NASA FY 2011 budget request includes \$3.1B over five years to develop affordable engines for use by multiple customers (NASA, other government agencies, and commercial) with associated technologies to support those engine development activities. While this plan includes funding for the development of the necessary propulsion systems and enabling technologies for a future heavy lift launch vehicle, it does not directly provide for such a vehicle. Main propulsion systems development is typically the critical path item in any launch vehicle development therefore this new plan will allow for NASA to start development early on the most challenging part of a launch vehicle development to reduce risk.

7. **Based on the President's FY11 plan, including the out years, when would you predict that such a heavy-lift capability would be ready for use? (Initial operating capability)**

   Answer: During his visit to KSC, the President specifically recognized the need for a heavy lift launch capability to carry humans beyond LEO by requiring a decision on a vehicle design no later than 2015. Such a decision would include setting performance goals, identifying lift capability and selecting the general vehicle design – work that will ultimately lay the path for launching a spacecraft for crewed missions into deep space.

   The FY 2011 budget request includes funds for NASA to conduct the important R&D and analysis necessary to make an informed decision on a heavy-lift vehicle no later than 2015. A primary focus of this effort will be to conduct research and development on a U.S. first-stage hydrocarbon engine for potential use in heavy lift and other launch systems, as well as basic research in areas such as new propellants, advanced propulsion materials manufacturing techniques, combustion processes, propellant storage and control, and engine health monitoring. Additionally, NASA will initiate development and testing of in-space engines. Areas of focus could include a liquid oxygen/methane engine and lower-cost liquid oxygen/liquid hydrogen engines. This work will build on NASA's recent R&D experience in this area, and the test articles will be viewed as a potential prototype for a subsequent operational engine that would be re-startable and capable of high acceleration and reliability. These technologies will increase our heavy-lift and other space propulsion capabilities and is intended to significantly lower costs – with the clear goal of taking us farther and faster into space consistent with safety and mission success criteria. In support of this initiative, NASA will explore cooperative efforts with the Department of Defense and also develop a competitive process for allocating a small portion of these funds to universities and other non-governmental organizations. This research effort along with many of our new technology initiatives will be coordinated with the broader Agency technology initiative led by NASA's new Chief Technologist.

   On May 3, 2010, NASA issued a Request for Information (RFI) seeking general information regarding potential launch or space transportation architectures (expendable, reusable, or a hybrid system) that could be utilized by multiple customers (e.g., NASA, commercial and other Government agencies). The RFI solicits information regarding propulsion system characteristics; technology challenges for propulsion systems; as well as innovative methods to manage a heavy-lift development program to include effective and affordable business practices. The RFI is open to the broad space community, including commercial, other Government agencies and academia. Information obtained from the RFI will be used for planning and acquisition-strategy development for current heavy-lift planning activities, funded in the FY 2010 Consolidated Appropriations Act (P.L. 111-117). Related to the RFI, on May 19, 2010, NASA posted a draft Broad Area Announcement (BAA). This draft BAA is soliciting proposals for a Heavy Lift and Propulsion Technology Trade study and seeks industry input on technical solutions in support of heavy lift system concepts studies. This draft BAA requests offerors to expand upon the previous NASA technical assessments and a final BAA solicitation will incorporate information obtained via the RFI as well as inputs from the upcoming Exploration workshop. These concept studies will include architecture assessments of a variety of potential heavy lift launch vehicles and in-space vehicle architectures employing various propulsion combinations and how they can be deployed to meet multiple mission objectives. Please note, the BAA is addressing FY 2010 planned activities which may also contribute to future plans and activities.

8. **My understanding is that NASA's estimate in the spring of last year for developing Ares V was that by 2020 through the first flight of Ares V, the cost of development plus production costs would be $16.5 billion dollars. If Ares I were not completed, which means we could not benefit from the way the two programs were designed to use some of the same technology, then that fact would result in a cost for Ares V and of about $27 billion. Our staff was told last Friday by the CFO that the cost of developing a heavy lift rocket would be 30-50 billion dollars. What engineering data have you obtained since spring of 2009 which leads to this incredibly inflated figure of 50 billion dollars?**

Answer: NASA has not established a formal cost estimate for Ares V, nor has NASA established a formal cost estimate for a similar heavy-lift capability. Additionally, no additional engineering data has been obtained to influence these cost estimates. However, the Agency has developed rough, preliminary estimates for Ares V project costs – estimates that vary depending on which assumptions (i.e. schedule, budget year, shared costs etc.) are included in an estimate. Therefore, comparing one cost estimate against another can lead to a misunderstanding if the assumptions are not standardized or fully understood.

With regard to the $30-50B figure cited by NASA's Chief Financial Officer, NASA would like to clarify that those numbers are most closely related to the Ares V project and are rough cost estimates, based on varying assumptions. Based on preliminary Agency estimates, NASA anticipates that the Ares V project costs through 2020, including development and early production, would be $27B – similar to the $30B ballpark figure cited at hearing. The $50B estimate cited is comparable to Ares V costs, including development and early production through 2025 -- again, if Ares I were cancelled. However, none of the aforementioned estimates include any of the any of the supporting elements required for launch, such as ground facilities, mission control, and program integration, or any payload. Those costs would be additional. (Note: Ares I and V share substantial development and fixed costs such as shared hardware, which must be considered in any estimate for one vehicle without the other. Therefore, if Ares I were continued, Ares V project costs through 2020, including development and early production would be around $16.5B.

9. **The moon is 240,000 miles away. Mars is as close as 35 million miles away, but averages a distance of 48 million miles away. For a manned mission to Mars, do you believe we should first return to the moon and engage in some long-term missions there, on the surface and in orbit, to see how astronaut health is affected and how well long-term mission hardware performs?**

   Answer: On April 15, 2010, the President laid out the goals and strategies related to the FY 2011 budget request for human exploration of our solar system, including a sequence of deep-space destinations matched to growing capabilities, progressing step-by-step, beginning with crewed flight tests—perhaps a circumlunar mission—early next decade of vehicles for human exploration beyond LEO, a human mission to an asteroid by 2025, and a human mission to orbit Mars and return safety to Earth by the 2030s. The President also directed that NASA proceed to develop a crew rescue vehicle based on the Orion space capsule technology to support crew return requirements on the International Space Station, and providing a technological foundation for systems that can later take us beyond Earth's orbit. Whatever the destination, it will be imperative for NASA to research astronaut health issues for long-duration missions before attempting a manned Mars mission. For example, Astronauts will have to be self-reliant when it comes to health issues, so NASA would be able to test tele-medical capabilities, as well as to study physiological and biological risks associated with long-term exposure to a low-gravity environment

10. **Mr. Administrator, under this plan, what year do you predict U.S. astronauts could go to the Moon? What vehicle will get us there and what engineering data can you share with us to support your prediction?**

    Answer: The President and his staff, as well as my NASA senior leadership team, closely reviewed the Augustine Committee report, and we came to same conclusion as the Committee: the human spaceflight program was on an unsustainable trajectory. To continue on the previous path we had to decide to either continue the ISS, support a program to get humans beyond LEO, or to make even deeper cuts to other parts of NASA's budget. Further, we would have had insufficient funding to advance the state of the art in any of the technology areas that we need to enable us to do new things in space, such as lowering the cost of access to space and developing close-loop life support, advanced propulsion technology, and radiation protection. The President recognized that what was truly needed for beyond LEO exploration was game-changing technologies; making the fundamental investments that will provide the foundation for the next half-century of American leadership in space exploration.

On April 15, 2010, the President laid out the goals and strategies related to the FY 2011 budget request for human exploration of our solar system, including a sequence of deep-space destinations matched to growing capabilities, progressing step-by-step, beginning with crewed flight tests—perhaps a circumlunar mission—early next decade of vehicles for human exploration beyond LEO, a human mission to an asteroid by 2025, and a human mission to orbit Mars and return safety to Earth by the 2030s. In addition to investing in transformative heavy-lift technologies, the President called upon NASA to select a rocket design no later than 2015 and then begin to build it; a decision no later than 2015 means that major work on building a new heavy-lift rocket will likely begin two years sooner than in the previous plan. The FY 2011 budget request provides increased investment in other game-changing technologies development that will lead to a more affordable and sustainable approach for exploration beyond LEO. Additionally, the FY 2011 budget request ensures continuous American presence in space on the ISS throughout this entire decade, re-establishes a robust and competitive American launch industry, starts a major heavy lift technology program years earlier, and builds a technological foundation for sustainable beyond-LEO exploration of our Moon, near-Earth asteroids, Lagrange points, and ultimately Mars.

Under the FY 2011 budget request, NASA also plans to send precursor robotic missions to candidate destinations such as the Moon, thus paving the way for later human exploration of the Moon, Mars and its moons, and nearby asteroids. Like the highly successful Lunar Reconnaissance Orbiter (LRO) and Lunar Crater Observation and Sensing Satellite (LCROSS) missions that captured the Nation's attention last fall, future exploration precursor missions will scout locations, gather key knowledge and demonstrate technologies to identify the most compelling and accessible places to explore with humans and validate potential approaches to get them there and back safely. These missions will provide vital information—from soil chemistry to radiation dose levels to landing site scouting to resource identification—necessary to plan, design and operate future human missions. These missions will help us determine the next step for crews beyond LEO, answering such questions as: Is a particular asteroid a viable target for crewed mission? Do the resources at the lunar poles have the potential for crew utilization? Is Mars dust toxic? NASA plans to begin funding at least two dedicated precursor missions in FY 2011, and to identify potential future missions to begin in FY 2012 and/or 2013.

Additionally, a new portfolio of explorer scouts will execute small, rapid turn-around, highly competitive missions to exploration destinations. Generally budgeted at between $100-200M lifecycle cost, these missions will allow NASA to test new and innovative ways of doing robotic exploration of destinations of interest to future human exploration. Selected projects may provide multiple small scouting spacecraft to investigate multiple possible landing sites, or provide means of rapid-prototyping new spacecraft approaches.

11. Are there any exploration technologies under consideration which were not already considered in 2005 and 2008 when Congress passed the Space Act bills and authorized the Constellation programs? If so, what are they?

Answer: Since 2005, Exploration technology development has focused on maturing near-term technologies to support Orion and Ares I, and developing longer-term technologies to support Ares V, the Altair lunar lander, and lunar surface systems. Examples include thermal protection system materials for the Orion heat shield, lightweight composite structures for Ares V, cryogenic propulsion systems for the lunar lander, and the Lunar Electric Rover for exploring the lunar surface.

However, at the highest level, the President and his staff, as well as NASA senior leadership, closely reviewed the Augustine Committee report, and came to the same conclusion as the Committee: the human spaceflight program was on an unsustainable trajectory. To continue on the previous path we had to decide to either continue the ISS, support a program to get humans beyond LEO, or make even deeper cuts to other parts of NASA's budget. Further, we would have had insufficient funding to advance the state of the art in any of the technology areas that we need to enable us to do new things in space, such as lowering the cost of access to space and developing close-loop life support, advanced propulsion technology, and radiation protection. The President recognized that what was truly needed for beyond LEO exploration was game-changing technologies; making the fundamental investments that will provide the foundation for the next half-century of American leadership in space exploration.

In this budget request for FY 2011, the United States will pursue a new approach to human space exploration through the development and demonstration of transformative technologies and systems capabilities, and also robotic precursors to scout potential destinations. This budget challenges us to develop the necessary capabilities to send Americans to places that humans have not explored before, including longer stays at exciting new locations on the Moon, near-earth objects, strategic deep space zones called Lagrange points, and the planet Mars and its Moons. We have not sent people beyond LEO in 38 years, and this budget gives us the great opportunity to focus on scouting and learning more about destinations to further explore our solar system and to develop the game-changing technologies that will take us there. It is important that we pursue these objectives to continue leading the world in human space exploration.

While we cannot provide a date with certainty for the first human visit to Mars, we can identify essential capabilities needed for such a mission. These are outlined in the programs within this budget request. They are capabilities that have been recommended consistently for at least 24 years in national level reports of committees and commissions addressing future human space exploration.

For example, NASA will begin development of high power electric propulsion and nuclear thermal propulsion systems to reduce mass launched to low Earth orbit; in-space propellant storage and transfer systems to enable refueling of interplanetary transfer vehicles; closed-loop life support systems to reduce consumables such as water and oxygen on long-duration missions; advanced habitat systems incorporating inflatable structures and radiation shielding to increase crew living space and improve safety; aerocapture systems to reduce the mass of propellants required for braking into Mars orbit; and advanced telerobotics to allow astronauts in orbit to control robots on the surface of Mars before the crew lands.

12. In 2002, was NASA's peer review of the VASIMR engine concept which has been proposed as a fast Mars propulsion system favorable or unfavorable; and has any new research data come to light?

Answer: NASA convened a Peer Review Panel of experts in late 2002 to assess progress and provide recommendation on Variable Specific Impulse Magnetoplasma Rocket (VASIMR) to improve that NASA research effort to ensure the research was more responsive to NASA's goals and objectives. Part of the review panel's recommendations involved using competitive NASA Research Announcements (NRAs) to focus the effort, allowing a broad community, including universities, industry etc., to submit research proposals in the area of high-power electric propulsion topics.

As a result of this effort, NASA convened three different NRA Peer Review Panels consisting of national and international high-power electric propulsion experts from several NASA Centers, the Department of Energy, the U.S. Air Force and academia. All three panels evaluated VASIMR-related proposals and found that each proposal contained major weaknesses that could not be remedied. Some of VASIMR's major weaknesses included no proof-of-concept experiments demonstrating that the VASIMR concept could produce thrust on a thrust stand, inadequate plan to validate plasma detachment from the magnetic field lines, inherently low efficiencies, and major cost uncertainties due to immature thruster concept. During this timeframe, Dr. Chang-Diaz, who was leading the research project, was a NASA employee. He has since left the Agency and established his own private firm, Ad Astra, which continues to develop the VASIMR technology utilizing private funds.

Following the 2005 Exploration Systems Architecture Study, NASA canceled nearly all activities related to high-power electric propulsion, preferring to focus on near term technology development efforts in support of the Orion Crew Exploration Vehicle. The Constellation architecture also deferred the need for advanced electric propulsion technology and nuclear reactor power flight systems to a time frame beyond current near-term lunar exploration plans. Consequently, much of the advanced technology funding for space exploration was reduced or, in some cases, eliminated, resulting in several advanced technology efforts being terminated. Therefore, NASA's interest at that time in high-power electric propulsion systems such as VASIMR was minimal at best.

In December 2008, NASA and Ad Astra Rocket Company signed a Space Act Agreement (SAA) under the ISS National Laboratory "to facilitate and conduct a space flight test of a VASIMR engine on the ISS." The SAA established a series of five gates as milestones toward VASIMR demonstration project completion. The first of these gates, execution of a Payload Integration Agreement, was completed in June 2009. NASA and Ad Astra are currently progressing through a series of Technical Interchange Meetings to identify interfaces and ISS standard accommodations necessary to proceed to the second gate, successful completion of a Systems Level Preliminary Design Review.

Completion of a systems level Critical Design Review is the third gate. At this point, the VASIMR demonstration project would be sufficiently mature to determine launch carrier and manifest, as well as on-orbit ISS resource allocations. Currently, there remains a significant challenge to reduce the mass of VASIMR to within 3 metric tons so that it can be manifested on available vehicles. Since this obstacle remains unresolved at this time, it is impossible to project with confidence a schedule beyond PDR.

In general, however, NASA appreciates visionary researchers like Dr. Chang-Diaz, and the FY 2011 budget proposal reflects NASA's reinvigorated focus on critical R&D efforts.

The FY 2011 budget request, for example, introduces a new Heavy-Lift Research and Development (R&D) Program that will focus on developing game-changing technologies to help reduce cost overall by improving our space launch propulsion technologies. This effort will include development of a U.S. first-stage hydrocarbon engine for potential use in future heavy lift (and other) launch systems, as well as basic research in areas such as new propellants, advanced propulsion materials manufacturing techniques, combustion processes, and engine health monitoring. Additionally, NASA will initiate development and in-space testing of in-space engines. Areas of focus could include a liquid oxygen/methane engine and potentially also low-cost liquid oxygen/liquid hydrogen engines. This work will build from NASA's recent R&D experience in this area, and the test articles will be viewed as a potential prototype for a subsequent operational engine that would be re-startable and capable of high acceleration and reliability. These technologies will increase our heavy-lift and other space propulsion capabilities and significantly lower operations costs – with the clear goal of taking us farther and faster into space consistent with safety and mission success criteria. In support of this initiative, NASA will explore cooperative efforts with the Department of Defense and also develop a competitive process for allocating a small portion of these funds to universities and other non-governmental organizations. This research effort along with many of our new technology initiatives will be coordinated with the broader Agency technology initiative led by NASA's new Chief Technologist.

13. The Aerospace Corporation, in support of the Augustine Commission, multiplied all cost numbers by a factor of 1.51 regardless of current status of development. The Constellation Program, with four years of experience and reviews, was treated the same as a company coming in off the street with not much more than sketches and sales pitch cost numbers. Doesn't such an approach overstate the cost and schedule factors for the Constellation Program and understate the same factors for commercial approaches?

Answer: NASA was able to provide cost, schedule and other technical data about the Constellation Program to the Augustine Committee. However, given that NASA was not privy to all of the data about various topics gathered by members of that Committee, NASA cannot comment on the assumptions that the Committee made or took into consideration during its analysis. NASA respects the members of the Augustine Committee and thanks them for their service to the Nation.

14. The internal cost estimates by NASA are very different from those presented by the Augustine Commission. Wouldn't it be prudent to have NASA's IG or another independent accounting firm do a thorough analysis of the actual expected costs so we can benefit from as accurate as possible cost estimates before Constellation is terminated, and billions are handed out in contracts for yet another new approach to replacing the Shuttle?

Answer: The Administration conducted an independent estimate of the Constellation program through the Augustine Commission. That team reviewed the basis of the Constellation program's estimate and concluded that the human spaceflight program was on an unsustainable trajectory. Instead of developing a third estimate, resources would be better spent planning for an orderly transition of the Constellation program, capturing lessons learned, and assessing what was developed and the associated costs.

15. Are you (Administrator Bolden) willing to call for such a cost estimate study yourself?

Answer: The Administration conducted an independent estimate of the Constellation program through the Augustine Commission. That team reviewed the basis of the Constellation program's estimate and concluded that the human spaceflight program was on an unsustainable trajectory. Instead of developing a third estimate, resources would be better spent planning for an orderly transition of the Constellation program, capturing lessons learned, and assessing what was developed and the associated costs."

16. Given the fact that Space X is one of the two COTS contract winners, and we are still waiting on the three cargo demonstration flights which were supposed to be completed by the Fall of 2008, what engineering information does NASA now have to make you believe that the commercial sector can deliver faster than Ares I/Orion?

Answer: To clarify, the original Space Act Agreement (SAA), signed by NASA and SpaceX on August 18, 2006, detailed that three cargo demonstration flights were to be completed by September 2009, not the fall of 2008 as identified in the question.

Both commercial cargo development partners, including SpaceX, continue to make steady progress in achieving their cargo demonstration milestones. While each has experienced some milestone delays, this is not unexpected, since both partners have aggressive, success-oriented schedules, and are facing challenges typical of a space flight development program. As such, NASA sees no reason to doubt either company's ability to achieve its desired objectives – that of demonstrating commercial cargo delivery to and from the International Space Station in the 2011 timeframe.

More specifically, both funded COTS cargo partners have progressed through their system design milestones, all of which are paid SAA milestones. Meeting existing SAA milestones is a primary indicator of progress, and completion increases our confidence, however, it is not our only indicator. The Commercial Crew & Cargo Program Office (C3PO) maintains technical, programmatic, and schedule insight into our COTS partners' progress. The program office includes representation from the Safety Technical and the Engineering Technical Authorities who provide independent progress insight for each partner. The ISS program office maintains independent insight into partner progress as well, in order to verify ISS visiting vehicle interface and safety requirement compliance.

The C3PO has established the COTS Advisory Team (CAT) comprised of approximately 100 NASA technical experts from across the agency. These experts review partner technical and programmatic progress for each milestone and provide progress assessments to the C3PO. Additionally, they participate in all major design reviews providing technical review comments back to our partners. The CAT provides another method by which NASA gains confidence that our partners will be able performs their flight demonstrations.

As mentioned above, each COTS partner must successfully verify compliance with a detailed set of ISS interface and safety requirements prior to their planned ISS berthing missions. These requirements are imposed on all Visiting Vehicles wishing to visit to the ISS. Both COTS partners are currently working with the ISS program on a daily basis to ensure they meet the ISS visiting vehicle requirements, providing independent insight into their progress and building confidence.

17. You state that NASA will be responsible for the safety aspects of any commercial crew launch systems. NASA has always been responsible for that, and has given contractors instructions. When considering the criteria developed for the Orion capsule, and more specifically the criteria necessary for any version of Orion to be safe for LEO missions, are you going to apply at least those same criteria to any commercial capsule?

Answer: Safety is and always will be NASA's first core value. Therefore, NASA will ensure that any vehicle that carries U.S. astronauts meets stringent safety standards.

18. With regard to number 17, if not, why not? If yes, then what engineering and budget data can you provide to us to show that applying those safety criteria to the commercial capsule won't cost more than finishing Orion?

Answer: NASA cannot provide any engineering data because such data does not yet exist. Such data will be contingent upon issuance of a procurement announcement for commercial crew, and receipt and selection of a proposal(s).

19. One knock on Ares I is that it is too big and too expensive to service the ISS, but in fact isn't it true that Ares I was designed from the beginning for possible cargo and astronaut delivery to the ISS as well as beyond Low-Earth-Orbit and that any extra expense of choosing Ares I is offset by the fact that those development costs also can be applied in large part to Ares V?

Answer: Yes, Ares I was "big" for the ISS mission because it was also intended to support exploration missions. Additionally, the Ares-I had originally been designed to carry pressurized and unpressurized cargo variant of the Orion capsule, but those capabilities were dropped as it became clear they would not fit within the budget.

Upon further analysis following the 2005 Exploration Systems Architecture Study, NASA decided the Ares I should have five-segments with a J-2X upper stage engine to be consistent with what was needed for the Ares V. The complexity and size of the Orion Crew Exploration vehicle, which would be utilized for both ISS and beyond-LEO missions, also drove the need for additional Ares I performance since the Orion was designed for a lunar mission and eventually to transport up to six people for a Mars mission. As a result of this and other changes, the Ares I and V were designed to share development costs, thereby lowering the overall lifecycle costs in the long run. Ares I and Ares V also were expected to share operational costs, such as annual fixed costs for vendor production base and sustaining engineering since both vehicles would use similar solid rocket boosters, upper stage engines and avionics. Thus, given shared operational costs, the overall lifecycle for both vehicles was expected to be lower.

20. Marginal costs for an Ares I are about $177 million per mission in FY 2016 dollars. According to your staff, NASA is currently paying the contractors an average of $59 thousand per kilogram delivered to ISS. What is the marginal cost of the commercial rocket, or rockets, you expect to use to deliver cargo to the ISS and do you have a written agreement in place so that once Constellation is terminated, the Commercial providers won't discover some new factors which would result in a much higher charge per rocket? If not, do you plan to seek one?

Answer: NASA awarded two firm, fixed-price Commercial Resupply Services (CRS) contracts to Space Exploration Corporation (SpaceX) and Orbital Sciences Corporation (Orbital) for ISS cargo delivery and return services in December 2008. NASA has a firm-fixed purchase price through the contract period that ends at the end of 2015. The price per mission reflects two variables: a pre-specified capacity (kilogram) maximum, and whether the cargo will be pressurized or unpressurized. The contract does allow for additional services or capabilities based on a fixed cost schedule as defined in the contract. Based on the commercial acquisition contract with SpaceX and Orbital, NASA does have access to total mission costs that are procurement and competition sensitive, NASA does not have information on the marginal or standing cost to launch and operate the commercial cargo services.

21. There are two COTS contractor companies. Are either of them producing a vehicle that would lift more than the Delta IV, or the Atlas V?

Answer: No. Neither vehicle being developed for NASA use will be able to lift more than a Delta IV or Atlas V. The currently planned lift capabilities for the COTS vehicles are:

SpaceX : A Falcon 9 flight to the ISS would equate to 9.8 mT of thrust. For that mission, 3,310kg of ISS cargo could be carried by Dragon. This would be a total for both pressurized and unpressurized cargo. *

Orbital: A Taurus II flight to the ISS would equate to 5.2 mT of thrust. For that mission, 2,000kg of ISS cargo could be carried by the pressurized cargo module. *

*Please note, the numbers for both commercial cargo providers reflect configurations of the first resupply missions to the ISS.

However, NASA is aware that SpaceX is developing the Falcon 9 medium/intermediate class launch vehicle to support ISS cargo transportation demonstrations and the commercial resupply of station contract, as well as non-NASA customers. Some variants of Falcon 9 to certain orbits have performance levels at the low end of EELV capability. NASA is aware that SpaceX has concepts for a variant of the Falcon 9, called the Falcon 9 Heavy, which is projected to launch more than the current EELV fleet. However, this is a non-NASA development effort, so additional questions should be directed to SpaceX.

22. If not, then why are we using taxpayer dollars to pay the two COTS contractors to invent the same or lesser capabilities?

Answer: NASA's funded COTS partners were selected to develop and demonstrate an end-to-end cargo space transportation system that is safe, reliable, and cost-effective to meet the needs of NASA and other customers, which is delivery of cargo to/from the International Space Station. The launch vehicles being developed for use by NASA meet medium-class launch capability needs. NASA requires delivery of about 40 metric tons of cargo 2011-2015. NASA conducted a competitive procurement for these services and selected providers based on industry proposals. Medium class launch services meet the ISS requirements. In addition, NASA has future requirements for medium class launch services for science missions. While some missions require additional performance, across all of our programs, NASA's mission needs average only 1-2 per year in the intermediate to heavy class of launch vehicle.

23. What engineering and professional budget studies can you share with us to show that there will be enough private customers to support ULA, and two or more other commercial companies, so that the U.S. government does not end up having to support the payroll of these companies between U.S. government missions?

Answer: NASA has not done any market surveys. However, NASA has seen evidence from various commercial studies that suggest that the market can support multiple commercial cargo and crew providers. The statements of representatives of ULA, Orbital Sciences and SpaceX at a recent Senate hearing also support this conclusion. The hearing, entitled NASA Commercial Space Capabilities took place on March18, 2010, before the Senate Subcommittee on Science and Space.

24. Since the two COTS companies are behind their schedules, have you considered recompeting the COTS cargo contracts?

Answer: Both commercial cargo development partners continue to make steady progress in achieving their cargo demonstration milestones. While each has experienced some milestone delays, this is not unexpected, since both partners have aggressive, success-oriented schedules, and are facing challenges typical of a space flight development program. As such, NASA sees no reason to doubt either company's ability to achieve its desired objectives – that of demonstrating commercial cargo delivery to and from the International Space Station in the 2011 timeframe.

With regard to the Commercial Resupply Services contracts, NASA is depending on both companies to succeed at developing their respective commercial cargo capabilities. Prior to the final Shuttle flight, NASA will pre-position spares onboard the ISS with the final logistics flights to provide some margin for delay in commercial cargo services. Beyond that, there is no planned back-up capability for ISS commercial cargo. Timely commercial cargo capability is critical for effective ISS operations. Without commercial cargo capability, the crew size and research operations planned for ISS would need to be reduced.

25. We don't have to beg commercial companies to participate in the space program; to the contrary, they need government dollars to develop their products, and then government missions to survive economically. Since you are using taxpayer dollars, yet you plan to allow the commercial companies to make profits from the technology, what will be the minimum percentage threshold which you require in terms of how much of their own money is invested?

Answer: NASA is preparing a strategy to support the development of commercial crew transportation services so that the Agency is prepared to proceed if funding is provided in the final enacted FY 2011 budget. Because the FY 2011 budget request has not been approved and the development strategy is still preliminary, NASA cannot discuss details of such a strategy because that information is pre-decisional.

NASA did not specify a minimum level of cost sharing for Commercial Orbital Transportation Services partners because the Agency felt that it would be inappropriate to prejudge a potential partner's business case. NASA reviewed each proposal as a whole, and assessed each proposal based on its own merits. That included review and evaluation of the type of vehicle system proposed, the development process proposed, as well as market factors such as the potential for other non-Government customers, the amount of investment each company plans to contribute, the company's experience in similar endeavors, etc. No single factor is necessarily more important than another.

It is also important to note that, legally, the level of Federal investment in technology development does not determine whether a commercial company is entitled to make profits from the commercial use of Federally-funded technology. Since 1980, with the passage of the Bayh-Dole Act (with regard to small businesses, universities and non-profits) and 1983, under Executive Order 12591 (with regard to large business), it has been the policy of the Federal government to permit contractors and others who receive Federal funds to develop technology to retain the commercial rights to that technology, including the right to make a profit from technology developed with funds received from the Federal government. NASA retains the right to use the technology for government purposes. Consistent with the law and Federal policy, NASA encourages and will continue to encourage its contractors and partners to make commercial use of technology development funded by NASA.

26. The commercial companies do not yet have a Launch Abort System. Current NASA contractors and the U.S. taxpayer have spent millions developing an LAS. If a commercial company currently not one of the Primes for Constellation programs is awarded a commercial crew contract, do you plan to allow that company to use the LAS already developed?

Answer: NASA expects all commercial crew transportation systems to include some sort of launch abort system (LAS). Details of that requirement will be outlined in the requirements developed for any NASA-acquired crew transportation services. It may be possible for a bidder to propose using the current Orion LAS system to meet the Agency's requirements. However, NASA cannot say whether that would be an effective strategy until it finalizes requirements and is able to review proposals.

Commercial providers are encouraged to enter into business arrangements needed to help them develop their transportation systems, including working with NASA's current contractors to facilitate the integration of the Orion LAS into a commercial crew transportation system. NASA plans to encourage and facilitate the use of existing architectural elements in the development and demonstration of new commercial crew transportation capabilities.

27. Do you plan to allow that commercial company to have the right to make profits on that LAS?

Answer: As discussed above, under Bayh-Dole and EO 12591, NASA's current Orion contractors retain the commercial rights to the LAS. Because, NASA is currently preparing its strategy to support the development of commercial crew transportation system, we cannot prejudge what arrangements may be made with regard to the LAS or whether it is the only system that will meet NASA's requirements for a launch abort system. Therefore, until the Agency's strategy is released, NASA cannot discuss pre-decisional issues that are still being vetted within the Agency.

28. If the answer to 27 is yes, do you plan to have the commercial company reimburse the taxpayer? If not, why not?

Answer: As discussed above, under Bayh-Dole and EO 12591, NASA's current Orion contractors retain the commercial rights to the LAS. Because, NASA is currently preparing its strategy to support the development of commercial crew transportation system, we cannot prejudge what arrangements may be made with regard to the LAS. Therefore, until the Agency's strategy is released, NASA cannot discuss pre-decisional issues that are still being vetted within the Agency.

FRANK R. WOLF
10TH DISTRICT, VIRGINIA

COMMITTEE ON APPROPRIATIONS
SUBCOMMITTEES:
RANKING MEMBER—COMMERCE-JUSTICE-SCIENCE
TRANSPORTATION-HUD

CO-CHAIR—TOM LANTOS
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House of Representatives

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March 2, 2010

Legendary NASA Astronauts & Leaders Strongly Oppose Obama Plan to Kill Manned Spaceflight

Dear Colleague:

I wanted to share with you some of the comments I have received from key former NASA leaders and Apollo astronauts in reaction to the Obama Administration's plan to end U.S. manned spaceflight programs. Manned spaceflight and exploration is one of the last remaining fields in which the U.S. maintains an undeniable competitive advantage over other nations. I believe we would be short-changing America's future if we walk away from the bold challenge of President Kennedy who envisioned our nation as the world's leader in space.

Copies of these full letters and my statement to the Commerce-Justice-Science Appropriations Subcommittee are available at: http://wolf.house.gov/cjs

- **Former NASA Administrator Dr. Mike Griffin** wrote: 'I believe that this budget request advocates a strategy that is, frankly, disastrous for the U.S. human spaceflight program.' He added that this proposal clears the way for Chinese dominance in space.
- **Dr. Chris Kraft, the legendary Apollo flight director** and former Johnson Space Center director, said: "The U.S. Space Program is in great peril if the [p]resident's budget proposals are enacted."
- **Apollo 7 astronaut Walter Cunningham** said this proposal "accelerates America's downward spiral toward mediocrity in space exploration."
- **Apollo 17 astronaut and former U.S. Senator Harrison Schmitt** wrote that this proposal "would cede the Moon to China, the American Space Station to Russia, and assign liberty to the ages. Other [nations] would accrue the benefits - psychological, political, economic, and scientific - that the United States harvested as a consequence of Apollo's success 40 years ago. This lesson has not been lost on our ideological and economic competitors."
- **Apollo 16 astronaut Charlie Duke** said: "We cannot afford to lose our leadership in space. The Constellation program must be continued."
- **Apollo 10 and 17 astronaut and "last man on the moon" Gene Cernan** said: "Now is the time for wiser heads in Congress to prevail. Now is the time to overrule Mr. Obama's pledge to mediocrity. Now is the time to be bold, innovative and wise in deciding how we invest in the future of America."
- **Burt Rutan, X Prize winner and the true commercial space leader** who ardently opposes this budget proposal. Mr Rutan said: "An observer might think that I would applaud a decision to turn this important responsibility over to commercial developers. However, he would be wrong. Two years after Neil and Buzz landed on the moon, America led the world in awarding PhDs in science, engineering and math. Today we are not even on the first or second page...The motivation of our youth is the most important thing we do for our nation's long-term security and prosperity. NASA's role in that can be as critical as it was in the 60s if the taxpayers fund true Research and Exploration."

For more information, please visit http://wolf.house.gov/cjs or contact Thomas Culligan in my office at 5-5136.

Best wishes.

Sincerely,

Frank R. Wolf
Member of Congress

FRANK R. WOLF
10TH DISTRICT, VIRGINIA

COMMITTEE ON APPROPRIATIONS

SUBCOMMITTEES:
RANKING MEMBER—COMMERCE-JUSTICE-SCIENCE
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CO-CHAIR—TOM LANTOS HUMAN RIGHTS COMMISSION

Congress of the United States
House of Representatives
March 18, 2010

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Apollo 13 Astronaut Jim Lovell calls Obama Administration NASA proposal "catastrophic"

Dear Colleague:

Last weekend, legendary Apollo 13 Astronaut Jim Lovell told the BBC:

"Personally, I think [the Obama Administration proposal] will have <u>catastrophic consequences</u> in our ability to explore space and the spin-offs we get from space technology. <u>They haven't though through the consequences</u>."

Captain Lovell is the latest of the many former NASA leaders, astronauts, and spaceflight experts who have expressed serious concern about the administration's proposal. For copies of letters I have received from these spaceflight experts, please visit my Web site at http://wolf.house.gov/cjs.

Manned spaceflight and exploration is one of the last remaining fields in which the U.S. maintains an undeniable competitive advantage over other nations. I believe we would be short-changing America's future if we walk away from the bold challenge of President Kennedy who envisioned our nation as the world's leader in space.

Please do not hesitate to contact me or my staff member, Thomas Culligan, in my office at 5-5136.

Best wishes,

Sincerely,

Frank R. Wolf
Member of Congress

FRANK R. WOLF
10TH DISTRICT, VIRGINIA

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March 16, 2010

Astronauts Memorial Foundation Opposes Administration Abdication of Human Spaceflight and Exploration

Dear Colleague:

I write to call your attention to the attached letter from The Astronauts Memorial Foundation -- which honors and memorializes those astronauts who have sacrificed their lives for the nation -- raising concern about the consequences of the administration's abdication of NASA's human spaceflight and exploration programs.

The letter calls on President Obama to honor our fallen astronauts and their families by "vigorously support[ing] uninterrupted continuation of U.S. human spaceflight system."

The Foundation notes that following the loss of the Space Shuttle Columbia in 2003, Dr. John Clark, husband of Laurel Clark who perished on Columbia, said that American must remain a *space faring* nation and not become a *space fearing* nation.

This is the latest in the series of letters from former NASA leaders, astronauts, and spaceflight experts who have expressed serious concern about the administration's proposal. For copies of other letters I have received, please visit my Web site at http://wolf.house.gov/cjs.

Manned spaceflight and exploration is one of the last remaining fields in which the U.S. maintains an undeniable competitive advantage over other nations. I believe we would be short-changing America's future if we walk away from the bold challenge of President Kennedy who envisioned our nation as the world's leader in space.

Please do not hesitate to contact me or my staff member, Thomas Culligan, in my office at 5-5136.

Best wishes.

Sincerely,

Frank R. Wolf
Member of Congress

The Astronauts Memorial Foundation

AMF

March 5, 2010

President Barack Obama
The White House
1600 Pennsylvania Ave. NW
Washington, D.C. 20500

Dear President Obama:

The Astronauts Memorial Foundation honors and memorializes those astronauts who have made the ultimate sacrifice for our space program and our nation. These astronauts sacrificed their lives as pioneers in human space flight.

All of the astronauts who have flown subsequently would tell you that they succeeded by standing on the shoulders of their fallen colleagues. Neil Armstrong, Buzz Aldrin and Mike Collins were only able to fly Apollo 11 to the moon after we lost Gus Grissom, Ed White and Roger Chaffee on a simulated countdown to Apollo 1.

After Challenger, hundreds of improvements were made in design, manufacture and operation of human rated spacecraft. Those seven astronauts would be proud of what was learned and accomplished as a result of their sacrifices. The Astronauts Memorial Foundation was created during this time; including the Space Mirror Memorial and the Center for Space Education.

In a ceremony that we conducted in 2003 placing the names of the Columbia astronauts on the Space Mirror Memorial, Dr. John Clark, the husband of Laurel Clark, who perished on Columbia, speaking for the families of the Columbia crew, said that in spite of the risks, America must remain a *space faring* nation and not become a *space fearing* nation.

The astronauts who we lost serve as models for future generations to accept risks willingly in the pursuit of exploration and knowledge, so that they too can contribute to the continued success of our nation.

In order to honor those astronauts and their families who have sacrificed for all of the benefits of human exploration, and to allow Americans continued pride in our space program, we urge you to vigorously support uninterrupted continuation of U.S. human space flight systems, including the Space Shuttle, and to maintain NASA's leadership in space exploration.

Sincerely,

M. McCulley

Michael J. McCulley
Chairman of the Board
Former Astronaut

Steph Feldman

Stephen Feldman, Ph.D.
President

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Captain Gene Cernan
Apollo 10 and 17 Astronaut

With the submission of his 2011 budget, Mr. Obama is showing extreme naivety or else deliberately taking accountability for his calculated steps in dismantling America's leadership in the world – "spread the wealth" internationally and turn our country into a second-class nation – economically, militarily, technologically, and politically. This ideology flows against the grain of over 200 years of our history and the will of all Americans. The space program never has been nor will ever be an entitlement program – it's an investment in the future – an investment in technology, jobs, world respect and leadership, and perhaps most importantly the inspiration and education of our youth. The results of our commitment to space over the last four plus decades are now evident in our factories, homes, hospitals, in the world of communications, as well as the stimulus it has provided in inspiring our kids to dream "the impossible" and then go out and make it happen. Hardly a day goes by without a young 30, 40, or even 50 year old (teenager or younger during the day of Apollo) thanking me for the inspiration I gave him or her to become a scientist, engineer, teacher, technician or perhaps a member of our country's armed forces. It wasn't me, it was the dreams inspired by the challenge of going where no human had gone before and the opportunities that subsequently came within reach. Aviation and space have been a romance for over a hundred years – the true legacy of the Wright Brothers is not that we can fly higher, faster, and farther than ever before, but the inspiration and dreams instilled in all who followed in their footsteps to do what has never been done before, what others couldn't do, what others wouldn't do, or perhaps what others were afraid to do. This is America in which I grew up and the America I desperately want to save for my grandchildren.

Mr. Obama's budget has not one penny focused on human spaceflight, rather he sets aside nominal amounts (certainly by comparison with his extravagance elsewhere) for the private sector to develop a capability that "some day" may lead to a manned orbiting vehicle. I strongly support this concept made possible by the technology developed by NASA over the years, but this is space exploitation not space exploration, and we all know it will be a decade or more before the private sector provides a ready, safe and economical access to our near space environment. "Curiosity is the essence of human existence", and exploration is the way of satisfying our insatiable quest for knowledge. Mr. Obama also sets aside dollars for the development of technology – technology to do what? History demonstrates that the evolution of technology is subject to a need – a challenge, a crises or a combination thereof, such as Apollo, WWII, or energy independence. First comes the mission, then comes the development of technology to accomplish the established goals. The high risk technology did not exist when John F. Kennedy challenged us to "go to the moon and do the other things…" He was asking us to do what most believed impossible – what others thought could not be done. After Sputnik the world looked to America for an answer – they expected us to respond and we did, as in the past during WWII, but the "we" was not the few who had an opportunity to walk in space or call the moon their home. Those of us who had this unique opportunity were simply the tip of the arrow. It was the thousands of Americans, who by nature responded to the challenge, who were the strength behind the bow, that made each one of those steps into space possible.

And that brings me to the point of jobs.

The best and brightest minds at NASA and throughout the multitudes of private contractors, large and small, did not join the team to design windmills. If Mr. Obama's budget becomes the rule of the land, these technicians, engineers, and scientists, a generation removed from Apollo, yet re-inspired by the prospect of going back to the moon and on to Mars, will be gone – where I don't know – but gone. You want to invest in jobs – try taking some of those stimulus dollars and investing in space. These are the kinds of jobs that will eventually create more jobs – from the high tech engineer to the delivery truck driver.

Not only is human spaceflight and space exploration at risk, but the future of this country and thus the future of our children and grandchildren as well.

Now is the time for wiser heads in Congress to prevail. Now is the time to overrule Mr. Obama's pledge to mediocrity. Now is the time to be bold, innovative and wise in deciding how we invest in the future of America.

Gene Cernan
Apollo Astronaut

Dear Tom:

I have just read Astronaut Harrison Schmitt letter to you & Congressman Wolf. I heartily agree with every word. We cannot afford to lose our leadership in space. The Constellation Program must be continued.

Charlie Duke
Apollo 16 Astronaut

FORMER SENATOR SCHMITT FINDS NEW SPACE POLICY CEDES MOON TO CHINA, SPACE STATION TO RUSSIA, AND LIBERTY TO THE AGES.

(Harrison H. Schmitt is a former United States Senator from New Mexico as well as a geologist and former Apollo Astronaut. He currently is an aerospace and private enterprise consultant and a member of the new Committee of Correspondence.)

The Administration finally has announced its formal retreat on American Space Policy after a year of morale destroying clouds of uncertainty. The lengthy delay, the abandonment of human exploration, and the wimpy, un-American thrust of the proposed budget indicates that the Administration does not understand, or want to acknowledge, the essential role space plays in the future of the United States and liberty. This continuation of other apologies and retreats in the global arena would cede the Moon to China, the American Space Station to Russia, and assign liberty to the ages.

The repeated hypocrisy of this President continues to astound. His campaign promises endorsed what he now proposes to cancel. His July celebration of the 40th Anniversary of the first Moon landing now turns out to be just a photo op with the Apollo 11 crew. With one wave of a budget wand, the Congress, the NASA family, and the American people are asked to throw their sacrifices and achievements in space on the ash heap of history.

Expenditures of taxpayer provided funds on space related activities find constitutional justification in Article I, Section 8, Clause 8, that gives Congress broad power to "promote the Progress of Science and the useful Arts.". In addition, the Article I power and obligation to "provide for the Common Defence" relates directly to the geopolitical importance of space exploration at this frontier of human endeavor. A space program not only builds wealth, economic vitality, and educational momentum through technology and discovery, but it also sets the modern geopolitical tone for the United States to engage friends and adversaries in the world. For example, in the 1980s, the dangerous leadership of the former Soviet Union believed America would be successful in creating a missile defense system because we succeeded in landing on the Moon and they had not. Dominance in space was one of the major factors leading to the end of the Cold War.

With a new Cold War looming before us, involving the global ambitions and geopolitical challenge of the national socialist regime in China, President George W. Bush put America back on a course to maintain space dominance. What became the Constellation Program comprised his January 14, 2004 vision of returning Americans and their partners to deep space by putting astronauts back on the Moon, going on to Mars, and ultimately venturing beyond. Unfortunately, like all Administrations since Eisenhower and Kennedy, the Bush Administration lost perspective about space. Inadequate budget proposals and lack of Congressional leadership and funding during Constellation's formative years undercut Administrator Michael Griffin's effort to implement the Program after 2004. Delays due to this under-funding have rippled through national space capabilities until we must retire the Space Shuttle without replacement access to space. Now, we must pay at least $50 million per seat for the Russians to ferry Americans and others to the International Space Station. How the mighty have fallen.

Not only did Constellation never receive the Administration's promised funding, but the Bush Administration and Congress required NASA 1) to continue the construction of the International Space Station (badly under-budgeted by former NASA Administrator O'Keefe, the OMB, and ultimately by the Congress), 2) to accommodate numerous major over-runs in the science programs (largely protected from major revision or cancellation by narrow Congressional interests), 3) to manage the Agency without hire and fire authority (particularly devastating to the essential hiring of young engineers), and 4) to assimilate, through added delays, the redirection and inflation-related costs of several Continuing Resolutions. Instead of fixing this situation, the current Administration let go Administrator Griffin, the best engineering Administrator in NASA's history, and now has cancelled Constellation. As a consequence, long-term access of American astronauts to space rests on the untested success of a plan for the "commercial" space launch sector to meet the increasingly risk adverse demands of space flight.

Histories of nations tell us that an aggressive program to return Americans permanently to deep space must form an essential component of national policy. Americans would find it unacceptable, as well as devastating to liberty, if we abandon leadership in space to the Chinese, Europe, or any other nation or group of nations. Potentially equally devastating to billions of people would be loss of freedom's access to the energy resources of the Moon as fossil fuels diminish and populations and demand increase.

In that harsh light of history, it is frightening to contemplate the long-term, totally adverse consequences to the standing of the United States in modern civilization if the current Administration's decision to abandon deep space holds. Even a commitment to maintain the International Space Station using commercial launch assets constitutes a dead-end for Americans in space. At some point, now set at the end of this decade, the $150 billion Station becomes a dead-end and would be abandoned to the Russians or just destroyed, ending America's human space activities entirely.

What, then, should be the focus of national space policy in order to maintain leadership in deep space? Some propose that we concentrate only on Mars. Without the experience of returning to the Moon, however, we will not have the engineering, operational, or physiological insight for many decades to either fly to Mars or land there. Others suggest going to an asteroid. As important as diversion of an asteroid from collision with the Earth someday may be, just going there hardly stimulates "Science and the useful Arts" anything like a permanent American settlement on the Moon! Other means exist, robots and meteorites, for example, to obtain most or all of the scientific value from a human mission to an asteroid. In any event, returning to the Moon inherently creates capabilities for reaching asteroids to study or divert them, as the case may be.

Returning to the Moon and to deep space constitutes the right and continuing space policy choice for the Congress of the United States. It compares in significance to Jefferson's dispatch of Lewis and Clark to explore the Louisiana Purchase. The lasting significance to American growth and survival of Jefferson's decision cannot be questioned. Human exploration of space embodies the same basic instincts as the exploration of the West – the exercise of freedom, betterment of one's conditions, and curiosity about nature. Such instincts lie at the very core of America's unique and special society of immigrants.

Over the last 150,000 years or more, human exploration of Earth has yielded new homes, livelihoods, knowhow, and resources as well as improved standards of living and increased family security. Government has directly and indirectly played a role in encouraging exploration efforts. Private groups and individuals take additional initiatives to explore newly discovered or newly accessible lands and seas. Based on their specific historical experience, Americans can expect benefits comparable to those sought and won in the past also will flow from their return to the Moon, future exploration of Mars, and the long reach beyond. To realize such benefits, however, Americans must continue as the leader of human activities in space. No one else will hand them to us. Other than buying our national debt, China does not believe in welfare for the U.S.

With a permanent resumption of the exploration of deep space, one thing is certain: our efforts will be as significant as those of our ancestors as they migrated out of Africa and into a global habitat. Further, a permanent human presence away from Earth provides another opportunity for the expansion of free institutions, with all their attendant rewards, as humans face new situations and new individual and societal challenges.

Returning to the Moon first and as soon as possible meets the requirements for an American space policy that maintains deep space leadership, as well as providing major new scientific returns. Properly conceived and implemented, returning to the Moon prepares the way to go to and land on Mars. This also can provide a policy in which freedom-loving peoples throughout the world can participate as active partners.

The Congressionally approved Constellation Program, properly funded, contains most of the technical elements necessary to implement a policy of deep space leadership, particularly because it includes development of a heavy lift launch vehicle, the Ares V. In addition, Constellation includes a large upper stage for transfer to the Moon and other destinations, two well-conceived spacecraft for transport and landing of crews on the lunar surface, strong concepts for exploration and lunar surface systems, and enthusiastic engineers and managers to make it happen if adequately supported. The one major missing component of a coherent and sustaining deep space systems architecture may be a well-developed concept for in-space refueling of spacecraft and upper rockets stages. The experience base for developing in-space refueling capabilities clearly exists.

Again, if we abandon leadership in deep space to any other nation or group of nations, particularly a non-democratic regime, the ability for the United States and its allies to protect themselves and liberty will be at great risk and potentially impossible. To others would accrue the benefits – psychological, political, economic, and scientific – that the United States harvested as a consequence of Apollo's success 40 years ago. This lesson has not been lost on our ideological and economic competitors.

American leadership absent from space? Is this the future we wish for our progeny? I think not. Again, the 2010 elections offer the way to get back on the right track.

To Thomas Culligan.

I would like to strongly endorse the inputs made by Dr. Michael Griffin to Congressman Wolf in preparation for the hearings on the 2011 NASA budget.

The U.S. Space Program is in great peril if the President's budget proposals are enacted.

In a recent article which I wrote which was published in the December 14, 2009 Space News (enclosed) I voiced similar concerns as Dr. Griffin. I stated clearly what my concerns were and what I believed to the best course for the nations human space flight program.

Please include my support to Congressman Wolf for staying the course and the NASA Constellation Program

Christopher C. Kraft, Jr
Retired Director, NASA Johnson Space Center.

Eugene F. Kranz
Former Director of NASA Mission Operations
Mission Controller on Mercury, Gemini and Apollo Programs
Directed the flight control team for the first lunar landing and Apollo 13 crew

A National Treasure

The current NASA team is a national treasure. From the early years of spaceflight, this team has been on the front lines and assured our Nation's leadership in space, science, and technology. The cancellation of the Constellation Program will result in the loss of skilled leadership and the talented NASA and contractor workforce. This action will cripple America's space efforts for many years to come.

In our early years in space, our leadership and mid-level management came from our Nation's research laboratories and from a vigorous aircraft industry. The leadership, experienced in design, development, and test, provided for a rapid maturing of the young engineers, who were inspired by President Kennedy's lunar challenge, and who joined our ranks. The Mercury and Gemini Programs provided the training ground for this young team to rapidly develop maturity and acquire the skills needed for Apollo.

If there is no continuity in the NASA and contractor leadership and an experienced workforce, any subsequent space effort will be severely challenged to develop the program management and operations skills while simultaneously establishing a highly complex program. This new team will repeat many of the same mistakes we made in the early years and will relearn the same lessons the hard way. There is no substitute for a well-experienced team to meet the challenges of a new space endeavor.

This is an unnecessary risk to be levied on the future program and its generation of leaders and must be avoided at all costs. If there is no continuity, future programs will ultimately incur more cost, development, and schedule problems.

For almost four decades, I directed the workforce that planned our space missions, developed the plans and procedures, and trained astronauts and controllers for the unforgiving and high risk aspects of spaceflight.
I am well aware of the challenges of developing leadership and building a competent and well-qualified space team. I was a member of the NASA

Space Task Group, directed the flight control team for the first lunar landing and the return of the Apollo 13 crew, and finally served as Director of NASA Mission Operations during the Shuttle era.

The current generation of NASA and contractor engineers, scientists, and technicians is incredibly talented, fully experienced, and well led. They continue the heritage of the earlier generations of space pioneers and continue the legacy we established. Today's NASA team is a national treasure, an essential element of our Nation's future in space.

Eugene F. Kranz
NASA Director of Mission Operations, Retired

Have We Lost the Will?

By Walter Cunningham

Except in wartime, there has never been, and likely never will be, another government program that produced as much technological innovation as the U.S. space program. No other program has so successfully infused the economy, rallied the nation, inspired youngsters toward academic achievement or established the U.S. as the world leader in technology.

In spite of this, on 1 February of this year, President Obama announced the cancellation of the Constellation Program of exploration. That announcement, putting NASA's future in doubt, triggered heated discussion. It is as if President Ford had cancelled the Space Shuttle Program in 1975, just as the last Apollo mission was being flown. The Shuttle Orbiter development was well underway at the time, but that did not save us from a six-year gap before the next American was launched into space.

Today, there is no realistic successor for human space flight waiting in the wings.

Our biggest loss from that first gap was the best and brightest of the NASA engineers and scientists who left to seek more challenging jobs. It took years to rebuild the professional team that eventually launched over 130 shuttle missions and constructed the most amazing engineering project in history—the International Space Station.

The Space Shuttle program not only maintained our preeminence in space, it raised our technical expertise and further increased our prestige among the developed nations of the world—precisely the same reasons why the Chinese are now working toward landing a man on the Moon.

Congress is our last hope of putting a stop to the dismantling of a once great agency. They are concerned about job losses and the economic impact, but in the long run, they are not near as costly as the loss of NASA as an inspirational vision for the next generation of space scientists, engineers and explorers.

While NASA and some administration supporters are trying to put the best positive spin they can on the budget proposal, the negative fallout continues to grow. The personnel requirements for NASA's new "vision" will do little to mitigate the huge losses from this foolish cancellation without a replacement in hand. The real loss, as in the 1970s, will be those trained and experienced engineers who are already leaving for more inspiring pursuits.

Administration spokesmen along with others are trying to rationalize the debilitating cut in the agency's programs. They claim the "$6 billion increase over the next five years demonstrates President Obama's strong commitment to space exploration." That is just over one percent a year and $2.5 billion of it is committed to the shutdown of Constellation, the same amount proposed for research on how global warming is affecting the Earth.

The $19B for 2011 is less than 0.5 percent of the proposed Federal Budget, one-ninth of what it was at its peak in the 1960s. The $300 million increase eliminates the one program that could drive human space exploration and sentences NASA to the same starvation diet it has existed on for several decades. It is about one-tenth of what the agency needs to continue operating a viable human space program.

NASA spin is touting "new technology development programs to expand the capabilities of future explorers"—in-orbit fuel depots, rendezvous and docking, closed-loop life support systems, heavy lift research and development of new engines, propellants, materials and combustion processes. These may sound new to someone unfamiliar with what NASA has been doing for 50 years, but (with one exception) they are pursuits for which NASA already has an unmatched reputation. Each would have played an essential role in the now cancelled Constellation program. Without the focus of a specific program, the *rason de tras* for these technologies is now "to advance the field of space science."

These supporting technologies have been retained, but the central hardware, Ares and Orion, have been cancelled. In their place, we now have increased spending on education, increased support for the discredited global warming hypocrisy and subsidies to several new "commercial" rocket companies. And, oh yes, don't forget a new outreach program to Muslim countries without established space programs.

In cancelling Ares/Orion/Constellation with nothing to take its place, the President is saying the U.S. should not have its own human space program and is directing funds to the COTS (Commercial Orbital Transportation Services) program. If NASA wants to participate in human spaceflight, it will have to be through contractors.

NASA has always contracted most of its hardware and service needs. Some of the contractors were successful in private industry, and sometimes the government was the sole customer. A company dependent solely on government grants, contracts and guarantees, is not a free market, private enterprise.

To succeed in the private sector a company must raise capital, develop a product, sell it at a profit and show a return on investment commensurate with the risk within a reasonable time frame. Unfortunately, space will <u>not</u> be an attractive commercial opportunity for the foreseeable future. Space exploration is a costly precursor to uncovering commercial opportunities, and it will be decades before a private investor can expect a return commensurate with the risk of exploration.

Until we find a way to make a profit in space, governments and countries are the only institutions able to afford space exploration and live with the extremely long term returns. That is why NASA must continue to develop the next generation human space system, whatever form that system may take. Human space systems cannot be evaluated solely on the basis of scientific return per dollar spent. Dominance in space gives our country credibility or leverage in so many ways other than economic gains; scientific discovery, understanding of the universe, international prestige, military stature and being seen as a country that can do anything we set our minds to.

The COTS program—companies selling services to NASA—made some sense with NASA still in the exploration business, doing the research and expanding the envelope of space travel beyond the Moon. It would be very difficult for private companies to replicate the singular competence NASA has developed, and even if COTS created vehicles are successful, they will be woefully inadequate for near term needs and will do nothing for exploration.

Only government programs—regardless of country—will get humans to the Moon and beyond. Space exploration is an environment from which a profit cannot be generated, leaving contractors supplying government sponsored programs that do not have to show a profit. After 50 years in space, how many lunar or interplanetary space probes have been launched by commercial space companies?

We have been told by the agency that future exploration programs, such as returning to the Moon or going to Mars, will be a global effort, not an American one. That may sound appealing with respect to sharing costs and other resources, but it virtually guarantees those programs will take longer, cost more and render them vulnerable to political bickering—like the ISS. As a result of the political decision to make the Russians a full partner, the ISS cost the U.S. $10 billion more, was two years late, and required that the station be placed in an orbit unacceptable for most alternative uses.

Has our country really degenerated to the point where we can no longer handle our own exploration? Did we spend $460 billion becoming preeminent in space, only to voluntarily surrender it? What does our new dependence on other countries to send Americans into space say about our culture, society and prospects for the future?

Americans need a frontier. Exploration is in our blood and we should be proud of it. Look at America's westward expansion, the Lewis and Clark expedition, Armstrong and Aldrin landing on the Moon.

NASA was always considered in a class by itself. Now, at a time when we are becoming increasingly dependent on space based systems, we seem bent on slipping back into mediocrity. How do you rationalize surrendering our preeminence in space? The last time a country voluntarily gave up their preeminent position in exploration was when the Ming government recalled the Chinese fleets in 1433. That critical error condemned China to worldwide stagnation for centuries.

NASA has always been a mission-driven agency that attracted a particular kind of individual. They focused on the objective, determined the obstacles, solved the problems and, in the end, accomplished the impossible. We all benefited from the technological fallout to our economy and our growing stature in the world. Continuing NASA's program of exploration requires three things: the technology, the resources, and the will to do it. We have plenty of the first two, but have we lost the will.

Trading American Preeminence for Mediocrity—or Worse
Walter Cunningham
Houston Chronicle, 2/7/10

President Obama's budget proposal may not be a death knell for NASA, but it certainly accelerates America's downward spiral toward mediocrity in space exploration. Now it's up to NASA's leaders to put the best face possible on this nail that the administration is trying to hammer into their coffin.

This proposal is not a "bold new course for human space flight," nor is it a "fundamental reinvigoration of NASA." It is quite the opposite, and I have no doubt the people at NASA will see it for what it is—a rationalization for pursuing mediocrity. It mandates huge changes and offers little hope for the future. My heart goes out to those who have to defend it.

NASA has always been a political football. Their lifeblood is money, and they have been losing blood for several decades. The only hope now for a life-saving transfusion to stop the hemorrhaging is Congress.

It is hard to be optimistic. President Obama has apparently decided the United States should not be in the human space flight business. He obviously thinks NASA's historic mission is a waste of time and money. Until just two months before his election, he was proposing to use the $18 billion NASA budget as a piggy bank to fund his favored education programs. With this budget proposal, he is taking a step in that direction.

NASA is not just a place to spend money, or to count jobs. It is the agency that has given us a better understanding of our present and hope for our future; an agency that gives us something to inspire us, especially the young people.

NASA's Constellation program was not "over budget, behind schedule, and lacking in innovation due to a failure to invest in critical new technologies." It was due to perennial budget deficiencies for this program. It would have been sustainable for an annual increase equal to the amount thrown away on the "cash for clunkers" program, or just a fraction of the tens of billions of dollars expended annually on Congressional "earmarks."

It's debatable whether Constellation was the best solution to President Bush's vision of "Moon, Mars and Beyond," but it was far better than the vacuum in which we now find ourselves, and without a viable alternative in sight.

Yes, jobs will be lost and the local economy will suffer. This will hurt and be readily measured. In the long run, intangible losses (those on which we cannot put a price tag) will be far more devastating.

The cancellation of Constellation will guarantee several things.

Most important, strategically, is the gap, the period during which we will be dependent on Russia to carry Americans to our own space station. With the cancellation of Constellation, that gap will grow longer, not shorter. American astronauts will not travel into space on American developed and built spacecraft until at least 2016 or 2017.

We are not trying to fix any deficiencies in Constellation; our fate will be in the hands of commercial companies with COTS (Commercial Orbital Transportation Services) program awards. They will attempt to regain our lost greatness with new capsules and new rockets or military rockets, after man rating them. Supposedly, they will do this faster and cheaper than NASA. Cheaper, maybe; faster is not going to happen. These will be companies that have never made a manned rocket and have little idea of the problems they face trying to man rate a brand new launch vehicle and space capsule.

Even under the best of circumstances, humans will not be flying to the ISS on COTS developed vehicles before 2017.

After fifty years and several hundred billion dollars, the accomplishments of NASA and the U.S. space program in science, technology and exploration are unchallenged. They are admired, respected and envied by people and countries around the world. Our space program has provided inspiration to the human spirit for young and old alike. It said proudly to the world that Americans could accomplish whatever they set their minds to. Look at the efforts of China and India in the last 30 years to emulate this success.

Young people have always been inspired with talk of sending explorers to the planets. Do you think they will have the same reaction when we speak of the new plan for "transformative technology development"?

NASA may have been backing away from the real challenge of human space flight for years, but in canceling Constellation and NASA manned vehicles, we are, in effect abdicating our role as the leading space faring nation of the world. America will lose its preeminence in space.

The real economic impact will not be immediate.

The public at large is not fully aware of NASA's role as a principal driver in our economy for the past 50 years. They forget that much of the technology we now take for granted either originated in the space program or was utilized and improved by the space program. That is NASA's real legacy. The investments we made in NASA in the sixties are still paying off in technology applications and new businesses.

The annual investment in NASA is not simply an expenditure; it is an investment—with a payback. The payback is generated because NASA operates at the frontiers of space, exploring the frontiers of our civilization.

At the frontiers of space, be it going to Mars, or constructing the most amazing engineering project in history—the International Space Station—huge obstacles, sometimes considered insurmountable, are encountered. NASA takes these obstacles as challenges that must be overcome to reach their goals. The solution may lie in new technology, or a new application of existing technology. These solutions eventually make their way into the marketplace with applications we never even dreamed of. NASA has tens of thousands of examples of these "spinoffs."

Now, after spending $11 billion on the development and close out of the Ares 1 launch vehicle and the Orion space capsule, we are eliminating them. Gone! And with them, most of NASA's human space flight program. In the ongoing struggle for leadership in science, technology and exploration, which was represented by America's pre-eminence in space, we have raised the white flag of surrender.

Who will this proposed budget please? It will please those who have opposed the Constellation Program and have a vested interest in an alternative plan; those who are against human space exploration and for unmanned exploration; and those who will benefit from the COTS Program.

None of this new "vision" sits very well with those of us who have known NASA at its best. From its inception, one of NASA's motivating forces was pride in being the very best, in displaying American leadership in human space flight, and maintaining the preeminence in space that derived from this attitude. It appears this attitude is foreign to a president who believes American preeminence should be avoided at all costs.

Mr. Obama, we do not want a space program that turns us into "just another country" among countries.

Thomas M. Culligan
Congressional Appropriations Legislative Assistant
The Hon. Frank R. Wolf (VA-10)

Tom,

I occasionally banter with my friend, Mike Griffin on subjects that include golf, the AGW scare and NASA policy. After sending him my latest tirade, he shared with me his recent letter to you regarding taxpayer-funded space research. I promised him that I would send you my thoughts on the debate, which follow:

From my past comments on NASA's post-mid-70s manned space efficiencies/accomplishments, an observer might think that I would applaud a decision to turn this important responsibility over to commercial developers. However, he would be wrong.

No question, it would be good to see commercial companies quickly succeed at orbital access and to take that capability beyond low earth orbit. However, I am fearful that the commercial guys will fail; i.e. they will do little more in my remaining lifetime than NASA accomplished in 3.5 years with Gemini in the mid 1960s. That would be a very big mistake for America to make, as we move into an era of real competition in space exploration as well as risk the loss of our leadership in nearly every other technical discipline.

Mike Griffin's excellent statement says it best; "I too want, in the strongest possible terms, to have government policies which serve to stimulate private development of space. But at the same time, I too am reluctant -- with an analogy to instrument flying -- to give up an airport where I know I can get in on the approach, for one where I might".

What I would like to see is a decade or two of overlap - an initial push in the commercial arena of manned spaceflight (Development programs, not Research programs), while NASA flies risky new ideas (read, true Research programs, giving at least a chance of discovering an important new Breakthrough), and at the same time pushes the forefront of Exploration beyond the earth's moon.

Imagine how much better America could motivate our youth if we were spending the billions of Stimulus Package money on making real progress in our efforts to someday colonize off the planet.

Two years after Neil and Buzz landed on the moon, America led the world in awarding PhDs in science/engineering/math. Today we are not even on the first or second page and most of our University's technical graduates take their skills back to their own countries to compete with us. The motivation of our youth is the most important thing we do for our nation's long-term security and prosperity. NASA's role in that can be as critical as it was in the 60s if the taxpayers fund true Research and Exploration.

The attachment is a photo I took at the Shuttle STS-130 launch - Caption: "Reaction when told about the President's NASA directive to abandon manned spaceflight".

As always, I am ok with the distribution of my thoughts without limitation.

While I usually offer candid remarks at the drop of the hat, I am not interested in Congressional testimony, since under duress I occasionally have been known to blurt out the truth. I have no interest in being in the same room with John Holdren..... Taking a line from a very old play: "I must turn away, least I soil my hands with the blood of a fool"

Burt Rutan

128 Intracoastal Drive
Madison, AL 35758
23 February 2010

Frank R. Wolf
Congressman, 10th District, Virginia
U.S. House of Representatives
241 Cannon House Office Building
Washington, DC 20515-4610

Dear Mr. Wolf,

First, I want to thank you for your kind gesture in soliciting my thoughts in regard to the president's budget request as it regards NASA and our nation's human spaceflight program.

Second, I believe that this budget request advocates a strategy that is, frankly, disastrous for the U.S. human spaceflight program, a crown jewel of this nation's achievements in the long history of human affairs.

Third, I must explicitly note that the fault with this budget lies *not* in the total amount – the so called "top line" – recommended for NASA, but in the *choices* which are offered concerning how the money should be allocated. In fact, the FY11 budget for NASA offers the best top line for the agency since the FY05 budget request was put forth in February 2004. The FY05 request was mooted, however, when President Bush failed to prevent the Office of Management and Budget (OMB) from implementing some $12 billion of critical reductions and offsets to NASA's human spaceflight budget over the years FY06-09.

While President Obama has not restored the funding lost in those years, and in fact recommended further out-year cuts in his FY10 budget amendment, beginning in FY11 his administration has practically restored the NASA top line that was minimally necessary for a successful program of human exploration. Regrettably, he has chosen to accompany that budget with disastrously poor strategic choices concerning how it should be utilized. These choices embodied in the president's FY11 budget request are flawed for the reasons discussed below.

1) First and most importantly from a geopolitical viewpoint, the FY11 budget strategy clears the way for China to be the next nation to put its own people on the moon, and to establish a long-term human outpost on that body. I ask only that you imagine what

the relative standing of China and the U.S. will be in the world at large when they can send astronauts and scientists to the moon, and we cannot. Societies, nations, and alliances form around those who lead. No one clusters around those who once led. The world civilization of the future will be shaped by those who are perceived to be leaders. We have a choice to make, now, as to whom we want that leader to be.

2) The FY11 budget strategy signals a clear departure from the program of activity authorized for NASA by the Congress not once, but twice, in 2005 and 2008. The direction of civil space policy had been exhaustively reviewed and debated for nearly three years following the loss of Space Shuttle *Columbia* in February, 2003. The Congress had decided upon its direction, had appropriated funds toward that end, and had reaffirmed its earlier decision in 2008. The U.S. space program cannot possibly produce useful results in response to significant course changes offered every few years by a new president. This is a case where Congress should "just say no".
3) Masked in all of the debates being promulgated by the media and various political pundits is the fact that the choice confronting NASA and the nation's civil space program is not one concerning the details of space architecture strategy and rocket design. NASA is perfectly competent to decide such matters at the career-staff level; no other organization is, and that is where such matters should be placed. This is why we have a National Aeronautics and Space Administration. The actual choice confronting us today is at a higher level. *The choice confronting us concerns whether there will in fact be a NASA-led human spaceflight program.* It is that simple. I believe that there are some things that are important for our society to do, that should not be left solely to the dictates of private enterprise, and that the expansion of the human frontier in space, with our nation in the lead, is one of those things. The FY11 budget plan takes NASA, and therefore our nation, off that path. In law, going back to the original Space Act of 1958, NASA is charged on behalf of our nation with the task of conducting missions to explore space, to develop the art and science of spaceflight, to expand and develop the human frontier. NASA is also charged with developing the necessary technology to carry out these missions. The FY11 budget strategy effectively eliminates NASA's role as a "space mission" agency, and renders unto it only the much-reduced role of "space technology" agency, while offering no U.S. government strategy by which we ensure the performance of those space missions believed by policy makers to be important to our future. If our policy is to leave the choice of what is to be done in space to be that which of interest to private enterprise, then in my opinion we are headed down the wrong path.
4) In connection with my comments in Paragraph (3), above, I cite Norm Augustine's recent remarks to the American Physical Society on 15 February. Norm indicated that he was not surprised to see Ares 1 cancelled: "Our conclusion is that it would likely be a

very fine launch vehicle, it would be very reliable; the question wasn't, 'can we build it', the question was 'should we build it'... "The current step, if you think about, was almost preordained," Augustine said later. "The view of our committee, the unanimous view, was that at least the Ares 1 had little chance of ever providing a useful role. I'm not questioning its technology, just its utility." Now, my regard and respect for Norm Augustine is nearly unbounded, but in his remarks above, his comments are more closely aligned with the interests of private contractors than of the U.S. government. Ares 1 and Orion are, quite simply, the U.S. government programs to provide for replacement of the U.S. Space Shuttle system, and to do so as rapidly as the pace of funding permits. To say that Ares/Orion should not be built, is to say that there should be no U.S. government human spaceflight system. It is to say that U.S. human spaceflight capability will exist, if it does, when and as it can be provided by contractors. To that point, I must then ask: What do you do when the contractor has spent the money which has been provided – up front – and the hardware isn't there? What do you do when the contractor wants to change the terms? How do you set the price when there is no comparable government solution and, quite possibly, no other private competitor? Who will be responsible if there is an accident, and who will bear the financial consequences? How will the U.S. government assure continuity of service in the event of an accident where the financial liability exceeds that of the supplier's assets? There are as yet no good answers to these questions. What we are seeing here is the obvious fact that contractors would – of course – prefer an environment where there is no government capability to set a limit as to how one-sided the terms and conditions can be.

5) The current use of the word "commercial" in discussing "commercial space" is difficult to understand. A commercial enterprise is one in which a hopeful purveyor of goods and services raises his own capital, brings his product to market, and sells it for what the market will bear. The plan advocated in the FY11 budget requires a huge up-front expenditure of government funds to sponsor the development of systems for which there is still no other market besides government, and for which there is unlikely to be any change soon. The only difference appears to be that we will be using new contractors who demand less government supervision. By this definition, an enterprise is "commercial" as long as it is not built by an established contractor working to government specifications with government oversight. Is this where we want to go?
6) Constellation – dismissively labeled the "program of record" – is being routinely branded as being "overrun and behind schedule." To that point, I refer you to this comment by Sally Ride, as quoted by Amy Klamper in *Space News*, 8/13/2009: Klamper noted "that while Constellation...funding...has been significantly diminished since former President George W. Bush called for a return to the Moon...the Aerospace Corp.

found that the program is largely on track and within the original funding profile." Augustine Commission member Sally Ride said, "The program comes pretty close to performing as NASA advertised as it would. ... NASA's planning and development phase of Constellation was actually pretty good."

7) The FY11 budget strategy completely ignores the recommendations of the Columbia Accident Investigation Board, to the effect that "The design of the (next) system should give overriding priority to crew safety, rather than trade safety against other performance criteria, such as low cost and reusability, or against advanced space operation capability other than crew transfer." (CAIB, p. 211)

I will close with the thought I have offered many times, in many venues, including to your Appropriations Committee in earlier years. The development and advocacy of commercial spaceflight for both cargo and crew has no stronger advocate than I. The efficiency of the free market, where it can serve us, has no stronger advocate than I. But not everything that is beneficial to the United States can be accomplished by means of private enterprise, and the expansion of the human frontier into space – cited correctly by the Augustine Committee as *the* key reason to have a human spaceflight program at all – is one of those things. The development of commercial spaceflight cannot come at the expense of government space missions, led by NASA, for the reasons I have cited above, among others.

The correct course for our nation is to hold course, to stay on track with Constellation, and to fund it appropriately.

Thank you.

Sincerely,

Michael D. Griffin

Dutch von Ehrenfried
NASA Flight Controller
Mercury, Gemini, Apollo, ALSEP, ERTS, Skylab and Space Station Programs

I'm a past NASA Flight Controller who supported Mercury, Gemini, Apollo, ALSEP, ERTS, Skylab and Space Station. I am thoroughly disgusted with what this administration is doing to the country let alone the Space Program. I worked with Walt Cunningham and strongly support his views.

After the damage is done, will the country be able to undo the harm in time. In just one year, I now understand what Obama meant when he said he was going to fundamentally change America.

Good luck in your efforts.

Terry Watson
Former NASA Mission Controller

I was disappointed, but not surprised to hear that the current administration decision to cancel the manned portions of NASA's future programs. As a veteran of the Apollo and Skylab Programs at NASA JSC, and as a NASA shuttle "customer" for getting several scientific satellites on orbit, I can say with a certain degree of experience that man is needed in space.

While I have reservations about attempting to but man on Mars, mainly due to the extreme expense involved, and concerns about the need to return to the moon, I do believe it is important to maintain a US ability to put men into space.

First, we are the leading super power in the world today in part due to our strong commitment to aerospace and defense. With the emergence of China as a new world power, we must maintain our superiority.

Second, we need programs that will inspire our young people to advance in math, science and engineering. Man in space is a much more compelling image for our future leaders.

Terry Watson
Los Angeles, CA

Dr. Thomas D. Jones
STS Astronaut

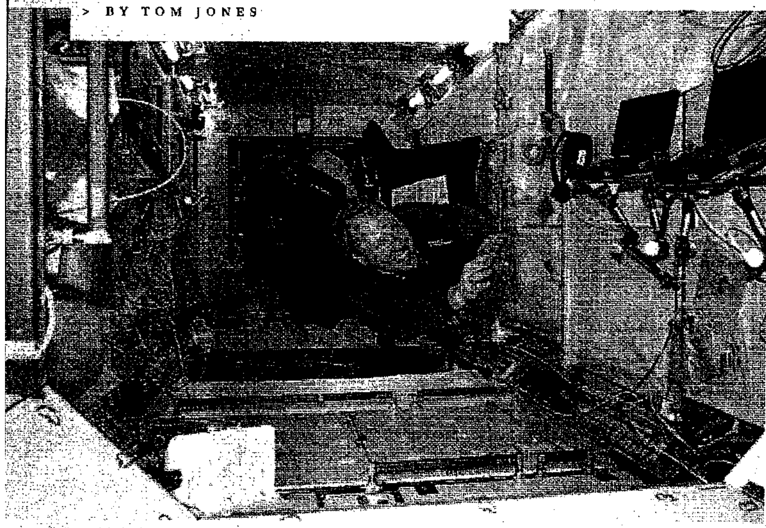
I am a four-time shuttle astronaut, specifically concerned about the safety and cost of committing all our access to low-Earth orbit, and the space station, to untried commercial vehicles. I'm also disappointed about the president's silence on committing the U.S. to human space exploration beyond low Earth orbit. I think this is the first move to eventually end U.S. human spaceflight altogether, in favor of mining the NASA budget to fund other domestic priorities.

Please contact me if I can help with testimony or background information.

Respectfully,
Tom Jones

AMERICA GROUNDED

> BY TOM JONES



PM'S RESIDENT ASTRONAUT SAYS DRASTIC BUDGET CUTS LEAVE NASA ON A PATH TO NOWHERE.

Tom Jones (foreground), International Space Station, 2001.

President Obama released his fiscal year 2011 budget on February 1, and his policy for NASA's human spaceflight program puts the nation on a course to second-class status in space. Instead of setting our national sights on the moon, nearby asteroids or more distant destinations, the president is declaring that human spaceflight is unimportant to U.S. interests.

He's not saying so directly. But his budget actions speak loudly. He has cancelled NASA's next-generation Constellation program, including the Orion spacecraft and the two rockets that were designed to return American explorers to deep space (see "Mission to the Moon," March 2007).

A little history: In the past 20 years, under three different administrations, NASA has lost more than 25 percent of its buying power. Despite those cuts, the agency managed to operate the shuttle and build the International Space Station (ISS). But it lacked a long-term goal in space. That lack of direction and the failure to replace the vulnerable shuttle led in part to the *Columbia* accident in 2003 that killed seven of my colleagues.

Now, seven years later, the presi-

ILLUSTRATIONS BY TEEKAY TEEKAY

dent's budget shows that he has already forgotten the lessons of *Columbia*. Without a goal worthy of the serious risks of human spaceflight, we will be putting our astronauts in danger to do nothing more than crew a research outpost. Even though I helped build the space station, it is not an ultimate destination. The ISS is a steppingstone to more ambitious exploration.

It is true that President Obama inherited a Constellation program (a return to the moon and deep space) that the Bush administration had underfunded by more than 35 percent since its inception in 2004. Because of that lack of support, Constellation is badly behind schedule. Those delays also raised costs for the development of the Ares I booster. Yet in October NASA successfully flew an early version of Ares I. While not a long-term successor to the shuttle, this rocket, with adequate funding, could be in service to ISS by 2015, restoring our own access to space.

The new budget seems merely an attempt to disguise the demise of U.S. leadership in space. The president does away with the Orion spacecraft and its Ares I and Ares V rocket boosters. The abrupt cancellation of the Constellation program means the U.S. no longer wishes to send its explorers to the frontiers of knowledge and the heights of spacefaring skill. We are deliberately choosing to have no better space capability than Russia, China or India.

During the peak of the shuttle program in the 1990s, we launched six or seven shuttles and about 40 astronauts per year into orbit for scientific and defense purposes. Starting next year, and for the foreseeable future, just four Americans will make it into space annually—as passengers on foreign rockets. Is this a bold new course for the nation?

After the shuttle orbiters retire by early 2011, American astronauts will rent seats on Russian rockets headed to the space station. We won't field an alternative spacecraft for five years or more. Instead, the president will farm out the nation's access to low Earth orbit to commercial firms. None of the industry rockets NASA has ordered to deliver cargo to the ISS has yet flown, and betting our nation's sole access to space on industry's ability to replicate 50 years of NASA experience on the fly is unwise. NASA should field its new crewed spacecraft as quickly as possible, then move to commercial firms once they have a proven record of reliable cargo services.

While NASA hopes its commercial effort will produce a ship that can service the ISS, the end of Constellation defers indefinitely the building of a heavy-lift rocket. Without such a Saturn V-class launcher, Americans will never get out of low Earth orbit (where we have been marooned for nearly 40 years). Instead, the Ares V heavy lifter has been replaced with "research and development" on building such a vehicle—someday. With no ability to launch humans past the ISS, we will watch, helpless to follow, as China pursues its determination to be the next nation to send its explorers into deep space.

THE ABRUPT CANCELLATION OF THE CONSTELLATION PROGRAM MEANS THE U.S. NO LONGER WISHES TO SEND ITS EXPLORERS TO THE FRONTIERS OF KNOWLEDGE… WE ARE DELIBERATELY CHOOSING TO HAVE NO BETTER SPACE CAPABILITY THAN RUSSIA, CHINA OR INDIA.

[redacted]

The president's rejection of a clear goal to send humans into deep space by a date certain eliminates a future in space for the brightest of our young scientists and engineers. The space-talent pool began emptying this winter, as promising innovators turn to careers in other industries. What student would pursue a career in space science or astronautics with the knowledge that the country deems leadership in space unimportant?

The president appointed his Augustine Committee last May to review the nation's human spaceflight plans. Of their recommendations, he accepted the move to put our human access to space on a commercial footing, with great uncertainty as to safety, schedule and cost. If this effort fails, the nation has no backup plan.

But the president rejected the most important of the Augustine observations—that a great nation must fund an exploration program worthy of its vision. In fact, the committee recommended an extra $3 billion per year to renew NASA's human exploration efforts. The president's team, however, chose to add only a billion dollars annually, missing a chance to remedy past underfunding and take the U.S. forward in space. Although the administration borrowed $787 billion last year for stimulus spending, finding $3 billion this year to stimulate our high-tech economy and talent pool proved impossible.

By proposing a budget for NASA that barely exceeds inflation, and failing to renew a commitment to send the U.S. beyond low Earth orbit, the administration is turning away from the dominance in space technology America has enjoyed since Apollo. This nation once put its confident footprints on the moon. Following the president's misguided course, we will trudge in retreat from the frontiers and promise of space. PM

Tom Jones, a member of the PM Editorial Board of Advisors, is a scientist, speaker, author and four-time NASA shuttle astronaut. His latest book is Planetology: Unlocking the Secrets of the Solar System.

Captain Jon McBride
Former Astronaut and NASA Assistant Administrator

I am a retired astronaut; and, in one of my previous lives I was Congressional Director for NASA (for DR James Fletcher, Bill Nelson was in the House, under Presidents Reagan and Bush).

Obviously, I have nothing against the heritage, and the decades-long list of the rank and file membership of this great NASA family of ours. They all have carried, do and will "carry the mail" for the President (I did the same thing years ago. You do it, or you move on!!) My problem is, has been, is and will be; Washington, DC is missing (and has missed) the whole point of the matter for years.

We (Americans) deserve better. We deserve, have earned and should have "it all"; i.e., continuous manned access to low earth orbit, a part in the International Space Station (for as long as practical / feasible; not an arbitrary 2020 shut-down, without an input from our international partners); and, long-range manned and robotic exploration of Moon, Mars and beyond. If it takes $30B / year to do that, that's what we Americans deserve. It's a good bet that Congress and the current and previous administrations lose track of that much, annually, on "no-return" appropriations.

As has been bantered and debated for years, we (Americans and our Congress) need to decide that it is jurisprudent to reinvest a certain percentage of our Federal budget on Research and Development (R&D); no matter which party is in control of the White House or the Congress (it's just good common sense, substantiated by years of resulting preeminence, not only in space exploration; but also, in the trickle-down and positive influence on education, national security, military prowess, the overall economy and , believe it or not, "National Pride" in being an American). NASA (and what's left of pure R&D in America) should be treated as an "entitlement" and dealt with accordingly. You can't plan 10, 20 or 30 year scientific / explorative programs when every two years you face the potential of having another political change of control in either the Executive and / or the Legislative branches of our government.

You cannot "spend" your way out of economic chaos and "social problematics" without finding better ways to design, build, manufacture, produce, construct, influence, educate and inspire; all the things that NASA has done, is doing and will do in the future (assuming our politicians decide to do something innovative, robust, sensible, meaningful and long overdue). We (Americans) are at a pivotal point in our history: deciding whether to accept this latest (and continual) erosion of governmental support for what's logical and / or rational; or, to force our leaders (on both sides of the political fence) to stand up for one of "the things" that made us a great nation. This is not about NASA vs. the private sector, Democrats vs. Republicans, "space States" vs. "non-space States", Senate vs. the House, Bush policy vs. Obama policy; this is, simply, about America continuing to lead the way in science, technology, engineering and mathematics (how about a nice acronym; STEM?).

One final, big, over-riding question: why do we (Americans, Congress, the Administration and NASA) want to invest all the money in "STEM" programs, when there will be no place for our scientists, technicians, engineers and mathematicians to ply their skills?? I'll bet we have college seniors today who were inspired by the 2004 "Lunar/ Mars Initiative", entered college with aspirations of joining the NASA team to pursue that dream; and, now realize that their dreams are in the process of being dashed. Concurrently, we should consider some of today's high school seniors. They are poised in preparation for college, were considering a career in science, now (in light of the current situation) finding themselves questioning that course of action.

We are hearing (almost every day) that it's time "to stand up and shout" about something! Well, add this plea to your list; and, try to make it a priority!! Because, if we (collectively) can't happening in the space exploration arena; the "shouting" will not only intensify, but we will find in breaking out in more and more of the corners in this American society of ours.

Jon McBride (one of the lucky few to have escaped gravity for a prolonged period of time)
15 FEB 2010

PS / Since we (Americans) are getting out of engineering and design, research and development, manufacturing (light and heavy) and a robust space exploration program, we may want to consider developing a "STEML" program for all of our students. In order for our "STEM" students to be successful, they will need to be conversant / fluent in at least one foreign language ("L"), so that they can interact with their owners, supervisors and co-workers in whatever country they go to for their selected vocation (I would suggest Chinese).

Larry E. Bell
NASA Gemini, Skylab, and Life Sciences Programs

I am an individual that has been an employee of the National and Aeronautics Association and employee of the Johnson Space Center for some 35 years and a part time consultant to Boeing for Space Station for another 14 years. I was just shocked at the announcement of President Obama that he was killing the Constellation program which was the only ongoing manned space program the United States had and was to continue the long term advancement of technology and science for the United States.

When we started with the Mercury project in the very early 1960's the Russians were far ahead of the U.S. in all of the space exploration effort. By the time we landed on the moon in 1969, in answer to President Kennedy's charge, we were the international leaders. Now with the announcement by President Obama we are outsourcing our entire manned space travel to first the Russians and then China who is just entering the era of manned exploration.

This is going to kill the entire manned exploration in the United States and shut down the Johnson Space Center for all practical purposes, because we no longer will have a need for Astronauts, Training, Manned Spacecraft, Flight Control and engineering. While the Augustine committee gave four options the President he did not pick any of them. The commercial companies that he said is the answer to everything, have never built rockets or vehicles sufficient for manned usage. None of the firms mentioned have a demonstrated capability or reliability. It would take many years and investment of resources to gain the necessary features to be used for manned operations.

It may be that returning to the moon and outer exploration should wait for some other approach or a later date it is not even reasonable to stop a development of a new manned spacecraft and a booster to low earth orbit for cargo and crew until the commercial market can prove they can meet the requirements to provide first cargo to low earth orbit and eventually manned if demanded but not in the next decade or more.

The announcement last week will cause many thousands of jobs lost and out sourcing of our space future. The end of challenges to our young people to strive to excel in sciences and technologies. The Johnson Space Center has many second generation employees that follow our footsteps and are devastated by this action. The real shame in all this, at this stage, is it will cost more to terminate the Constellation program than it would have to build the Orion and at least the first stage of Ares.

In addition the Senate had a requirement in the appropriation bill for 2010 that said the Administration **must** come back to Congress before using 2010 funds for termination or change to the Constellation program, yet in spite of this law, the current administration has effectively done just that without going back to Congress, except in the 2011 budget submittal.

The Congress has to stop this Administration from killing the manned space program and violating the appropriation bill for 2010.

Your action in this matter is of extreme importance.

Larry E Bell

FRANK R. WOLF
10TH DISTRICT, VIRGINIA

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wolf.house.gov

March 2, 2010

Legendary NASA Astronauts & Leaders Strongly Oppose Obama Plan to Kill Manned Spaceflight

Dear Colleague:

I wanted to share with you some of the comments I have received from key former NASA leaders and Apollo astronauts in reaction to the Obama Administration's plan to end U.S. manned spaceflight programs. Manned spaceflight and exploration is one of the last remaining fields in which the U.S. maintains an undeniable competitive advantage over other nations. I believe we would be short-changing America's future if we walk away from the bold challenge of President Kennedy who envisioned our nation as the world's leader in space.

Copies of these full letters and my statement to the Commerce-Justice-Science Appropriations Subcommittee are available at: http://wolf.house.gov/cjs

- **Former NASA Administrator Dr. Mike Griffin** wrote: 'I believe that this budget request advocates a strategy that is, frankly, disastrous for the U.S. human spaceflight program.' He added that this proposal clears the way for Chinese dominance in space.

- **Dr. Chris Kraft, the legendary Apollo flight director** and former Johnson Space Center director, said: "The U.S. Space Program is in great peril if the [p]resident's budget proposals are enacted."

- **Apollo 7 astronaut Walter Cunningham** said this proposal "accelerates America's downward spiral toward mediocrity in space exploration."

- **Apollo 17 astronaut and former U.S. Senator Harrison Schmitt** wrote that this proposal "would cede the Moon to China, the American Space Station to Russia, and assign liberty to the ages. Other [nations] would accrue the benefits - psychological, political, economic, and scientific - that the United States harvested as a consequence of Apollo's success 40 years ago. This lesson has not been lost on our ideological and economic competitors."

- **Apollo 16 astronaut Charlie Duke** said: "We cannot afford to lose our leadership in space. The Constellation program must be continued."

- **Apollo 10 and 17 astronaut and "last man on the moon" Gene Cernan** said: "Now is the time for wiser heads in Congress to prevail. Now is the time to overrule Mr. Obama's pledge to mediocrity. Now is the time to be bold, innovative and wise in deciding how we invest in the future of America."

- **Burt Rutan, X Prize winner and the true commercial space leader** who ardently opposes this budget proposal. Mr Rutan said: "An observer might think that I would applaud a decision to turn this important responsibility over to commercial developers. However, he would be wrong. Two years after Neil and Buzz landed on the moon, America led the world in awarding PhDs in science, engineering and math. Today we are not even on the first or second page...The motivation of our youth is the most important thing we do for our nation's long-term security and prosperity. NASA's role in that can be as critical as it was in the 60s if the taxpayers fund true Research and Exploration."

For more information, please visit http://wolf.house.gov/cjs or contact Thomas Culligan in my office at 5-5136.

Best wishes.

Sincerely,

Frank R. Wolf
Member of Congress

Congress of the United States
Washington, DC 20515

March 11, 2010

The Hon. Charles Bolden
Administrator
National Aeronautics and Space Administration
300 E St, SW
Washington, DC 20546

Dear Administrator Bolden:

In light of the many questions surrounding the budget request for the National Aeronautics and Space Administration's (NASA) Exploration Program, we urge you to assemble a team of NASA experts -- appointed by the Johnson, Marshall and Kennedy Space Center directors -- to review how exploration spacecraft and launch vehicle development and testing may be maintained within the proposed budget request to ensure uninterrupted, independent U.S. human space flight access to the International Space Station and beyond. The team should report back within 30 days in order to provide the administration and Congress with this necessary information.

President Obama has repeatedly discussed the need for American students to pursue degrees in the science, technology, engineering, and mathematics (STEM) fields. However, by forsaking NASA's exploration spacecraft, launch vehicle and mission in the FY 2011 budget, we will lose a key inspirational program that motivates young Americans to pursue STEM careers. Space exploration has been the guiding star of American innovation. The Mercury, Gemini, Apollo, and Shuttle programs rallied generations of Americans to devote their careers to science and engineering.

For this and many other reasons, it is imperative that the United Stated remain the world's leading spacefaring nation. To maintain this leadership, we ardently believe that NASA must continue development of its own exploration spacecraft and maintain a robust human spaceflight program. Above all, NASA must have a clear exploration mission, timeline, goals, and a destination, and its funding must be carefully aligned with this exploration plan.

Under this administration's proposal, each of these critical elements is missing. The U.S. will have no exploration spacecraft or launch vehicles in development for the foreseeable future. By the time commercial low-Earth orbit vehicles are cleared for flight, U.S. astronauts may have nowhere to go. NASA will no longer have a clear vision on its direction and ultimately the U.S. will no longer be a spacefaring nation.

Fortunately, NASA's civil and contractor workforce contain the world's leading scientists, engineers, and human spaceflight experts. We believe they are ideally situated to review U.S. exploration systems and goals and to report back on how these may be maintained within the proposed budget. Specifically, the team should review how current exploration system development and tests may be accommodated within the current budget request. Concurrently, astronaut safety must be of paramount concern throughout this review.

We believe that this review is essential to the consideration of NASA's FY 2011 budget. We look forward to your response and the report of the NASA review panel.

Sincerely,

WEDNESDAY, MARCH 24, 2010.

NSF (NATIONAL SCIENCE FOUNDATION) FY2011 BUDGET OVERVIEW

WITNESS

ARDEN L. BEMENT, JR., DIRECTOR, NSF

Mr. MOLLOHAN. The hearing will come to order. Good morning. Welcome to the Fiscal Year 2011 National Science Foundation Budget Overview Hearing of the Subcommittee on Commerce, Justice, and Science.

Today we will cover the budget and operations of the National Science Foundation and the National Science Board and also review the status and future needs of U.S. science activities other than those in human health.

APPRECIATION OF DR. BEMENT

Our witness is the director of the National Science Foundation, Dr. Arden Bement. Dr. Bement, I believe this is your valedictory appearance before this Subcommittee, and I want to begin by thanking you for your service to American science and technology and to the people of the United States.

Dr. BEMENT. Thank you, Mr. Chairman. I appreciate that.

Mr. MOLLOHAN. Well, I think you are leaving NSF well staffed with science leaders, you have succeeded in efforts to bring forward major cross cutting initiatives, achieving cooperation across the different science dictorates, and between the education and human resources directorate in the science, technology, engineering, and the math programs.

And on a personal basis it has been a pleasure working with you, and I join everybody else who works with you in being extremely impressed with you as a scientist and as an administrator and as a person, it has been a real pleasure.

Dr. BEMENT. And I reciprocate that feeling.

Mr. MOLLOHAN. Thank you, Doctor.

DOUBLING THE NSF BUDGET

Based on considerable evidence, real growth in the U.S. economy in excess of population growth, it is primarily the result of innovations and new technologies that result from public and private investments and research and development.

Accordingly, we are in the midst of a ten-year doubling and funding for NSF contemplated by the America Competes Act. This doubling was accelerated by $3 billion added to the fiscal year 2009 appropriation for the Foundation as part of the American Recovery and Reinvestment Act. Those funds have gone to increase grant funding across all areas of NSF and to various science infrastructure investments.

The budget request for fiscal year 2011 continues the planned doubling with a roughly seven percent increase over the 2010 enacted levels.

STEM EDUCATION REFORM

In fiscal year 2010 this Subcommittee supported an increase to NSF education programs focused on hands on, inquiry-based instruction in grades K through 12 and in K through 12 teacher preparation.

Last month we heard testimony from those who work in this area, and they provided examples of successful efforts at improving science, technology, engineering, and math education. Those witnesses offered evidence of the benefits that result from federal investments made through NSF.

NSF has a major role to play in continuing and accelerating the reform of science education to include inquiry and student assessments of inquiry skills.

NSF CLIMATE RESEARCH

In addition, NSF plays a growing role in climate observations and research. Under the Major Research Equipment and Facilities Construction Account the request to initiate the National Ecological Observatory Network and to provide major funding for the Ocean Observatories Initiative should result in new understanding of how ecosystems and the oceans influence and respond to climate change.

These research networks, along with the NSF grants for critical zone observatories, new research in hydrology, and new super computer at the National Center for Atmospheric Research have the potential to support climate understanding predictions that are both more accurate and finer in spatial resolution. These improvements will be needed to assist the private and public sectors in choosing climate change adaptation strategies and investments.

BROAD SUPPORT OF RESEARCH

NSF is involved in so many exciting areas of research including math, genomics, computer science, and engineering. I could go on, but this breadth of activity is the unique mission of NSF.

While NSF and the mission agencies support R&D addressing changing national priorities, it is NSF's unique responsibility to ensure that the U.S. has continuing expertise across all areas of science and technology. This provides our Nation with the ability to address rapidly new challenges as they arise.

Given the critical role of science and technology in the future prosperity and international leadership of the United States, we look forward to hearing from you, Dr. Bement, on the state of U.S. science and technology and its future needs and prospects.

Following the opening statement of Ranking Member Wolf, we will ask you to provide a summary of your written statement which will be included in the hearing record and then we will go on the questions from Subcommittee members.

Dr. BEMENT. Thank you.

Mr. MOLLOHAN. Mr. Wolf.

Mr. WOLF. Thank you, Mr. Chairman.

I join the Chairman today and welcome you Doctor to the hearing to testify on the budget, and I am pleased to see the level of commitment to funding basic science and scientific research.

APPRECIATION OF DR. BEMENT

And I will just have the Director submit for the record. I just want to thank you for your service and to the country, and I think it is going to be a loss for our government to see you leave, but I am curious to see who they appoint.

And as we get into talking, since you are never coming back here again in the sense that nobody can ever fire you pretty much, why don't you really tell us how things really are?

Dr. BEMENT. Okay.

Mr. WOLF. No, no, I mean——

Dr. BEMENT. No, I understand.

Mr. WOLF. You are a father of how many kids?

Dr. BEMENT. Eight.

Mr. WOLF. Eight. And you are a grandfather of how many?

Dr. BEMENT. Thirty.

Mr. WOLF. So you take a different approach to maybe a 28 year old.

Dr. BEMENT. You could have kept going.

Mr. WOLF. Yeah. And how many great grandchildren?

Dr. BEMENT. Nineteen.

Mr. WOLF. Yeah, so I think you have a perspective. So I would hope when the hearing begins, in your testimony you would really tell us the truth and just let us know. Because I think I really worry that the Nation is ready to come into a period of decline.

I saw Charles Krauthammer's piece about a month and a half ago, he said, decline is a choice. As individuals we make a choice whether we want to decline, as great nations we make a choice.

And so I would just like to hear you really tell us where we are. There is all this research, going on, you have got the Board's Foundation, you got this group, you have Arne Duncan doing this.

Really so when you come and tell us, tell us really where you think not only as the head of the National Science Foundation, but as a father, and a grandfather, and a great grandfather somebody who has a perspective from a biblical wisdom, if you will, where you think the Nation is and what you think we have to do.

But I join the Chairman too in thanking you for your service over the many years. And thank you, Mr. Chairman.

Dr. BEMENT. Thank you.

Mr. MOLLOHAN. We are not suggesting that you had never not told us the truth though.

Mr. WOLF. No, but I think—well the reality is though when you work in the Administration—I used to work for a cabinet secretary who had different views than the White House, and you would sit in a meeting and you would know how he felt, then you would come up on the testimony and——

Mr. MOLLOHAN. You wouldn't hear it all?

Mr. WOLF. It would be different, so I want him to tell us the way it really is.

Mr. MOLLOHAN. Okay. Dr. Bement, we again welcome you and invite you to tell it the way it is.

Dr. BEMENT. Thank you, Chairman Mollohan, Ranking Member Wolf, and members of the Subcommittee, I am pleased to be here with you today.

PRESIDENT'S 2011 BUDGET REQUEST

The essence of the President's 2011 budget request for the National Science Foundation is to reaffirm the agency's roots as a Nation as well as bring us scientific innovation.

An assessed 2011 request is $7.4 billion, an increase of eight percent over 2010. This keeps us on the road to the President's and the America Competes Act goal of doubling NSF's budget.

But as with any budget this request reflects tough choices and clear priorities. It recognizes NSF's unique national responsibility for supporting basic research, our catalytic role in education, and the ongoing need for investments and stewardship.

NSF's research and education agenda is both multifaceted and well rounded. It is designed very deliberately to support the Administration's plan for making innovation a center piece of economic strength and future well being.

The main driver for this investment is the National Innovation Strategy. Nothing speaks more to what NSF is and does than the Administration's commitment to fundamental research, and that is emphasized throughout the budget.

You will also see NSF at the forefront of educating the next generation of 21st Century knowledge and skills. Let me highlight programs that are central to this goal.

The Advanced Technological Education Program supports new and enhanced two year college programs that educate technicians for the high-technology workforce. I might say parenthetically they also prepare a lot of teachers for STEM education in the schools.

The Graduate Research Fellowship and Faculty Career Development Program supports students and early career investigators to foster the Nation's next generation of scientists and engineers.

Climate change education addresses learning at all levels and is designed to stimulate careers in climate science.

NSF programs also support next generation information technology and secure cyberspace. NSF will support the interagency networking and information technology R&D program at $1.17 billion.

Overcoming challenges inherited, today's great scientific questions will require a new computer revolution to overcome the physical restrictions of today's silicon chip based technology.

NSF's Science and Engineering Beyond Moore's Law is a multidisciplinary research program designed to enhance our Nation's economic competitiveness. The program's name refers to the proposition that computer processing power based on semiconductor integrated circuits doubles about every 18 months; however, we are rapidly reaching the physical limitation of that progress.

NSF must continue to innovate in tackling the large scale scientific and engineering challenges of our age, including understanding the Nation's scope of changes in the earth's climate.

NSF contributes multiple resources to support the U.S. Global Change Research Program and other interagency initiatives that are helping us understand and confront the global challenge of a changing climate.

NSF's contribution to the U.S. Global Change Research Program is proposed to increase by 16 percent to $370 million.

Also in 2011, NSF will spend $766 million on a portfolio of activities called Science, Engineering, and Education for Sustainability. It will seek integrated approaches to increase U.S. energy independence, enhance environmental stewardship, and reduce energy use and carbon intensity while generating continued economic growth.

Regaining our Energy, Science, and Engineering Edge, or RE-ENERGYSE, is a new $19 million program to help the Nation regain its leadership in science and engineering by attracting and educating future scientists into the clean energy fields.

NSF will jointly fund RE-ENERGYSE with the Department of Energy to prepare as many as 8,500 highly trained young scientists and engineers for clean energy careers by 2015.

Additionally, RE-ENERGYSE will provide training of technicians for clean energy industries.

NSF's request includes $20 million in its Major Research Equipment and Facilities Construction account to begin construction of the National Ecological Observatory Network, or NEON.

NEON is a multi-faceted project with a total projected budget of $434 million spread out over the next six fiscal years.

NEON will collect data on the effects of climate change, changes in land use, and invasive species on natural resources and biodiversity.

NEON will be the first observatory network designed to detect and enable forecasting of ecological change on the continental scale over multiple decades.

As with any budget the most important information is the message between the numbers. In 2011 that message is the Administration's commitment to innovation and economic growth through science and engineering.

The Foundation is pleased to be playing an important role in that effect.

Mr. Chairman and Ranking Member Wolf, as this will likely be the last time I testify before you before my June 1st departure from the Foundation I want to make certain that you are aware of how deeply appreciative I am of your support over the past nine years as director of NSF.

And with that I would be happy to answer your questions.

[The information follows:]

Testimony of

Dr. Arden L. Bement, Jr., Director

National Science Foundation

Before the House Appropriations Committee

Subcommittee on Commerce, Justice, Science and Related Agencies

March 24, 2010

Chairman Mollohan, Ranking Member Wolf, and Members of the Subcommittee, I am pleased to present the National Science Foundation's budget for the 2011 fiscal year.

The National Science Foundation (NSF) proposes a fiscal year 2011 investment of $7.42 billion to advance the frontiers of research and education in science and engineering. Our budget request includes an increase of $552 million – or 8 percent – over the current fiscal year 2010 amount. This increase reflects the Administration's continued resolve to double overall funding for the Foundation.

The National Science Foundation is the only federal agency dedicated to the support of basic research and education across all fields of science and engineering. For 60 years, we have been exploring the frontiers of scientific knowledge and extending the reach of engineering by encouraging, identifying, and funding the best ideas and most promising people. The high-risk, potentially transformative investments we make generate important discoveries and new technology, create and train a dynamic workforce, and spark the curiosity and creativity of millions. Our investments in research and education help ensure that our Nation remains globally competitive, prosperous, and secure.

An investment in the National Science Foundation is a direct investment in America's economic security. In fact, without a solid basic research foundation for our high-tech economy, no economic security is possible. Basic research underpins all of the technology that constitutes the lifeblood of today's global market. America's sustained economic prosperity is based in part on technological innovation resulting from previous fundamental science and engineering research.

Innovation and technology are engines of the American economy, and advances in science and engineering provide the fuel.

While the United States still far outpaces the world in its level of public and private R&D investment and research output, our counterparts around the globe are well aware of the importance of funding R&D. As is highlighted in the just released 2010 Science and Engineering Indicators, the world's R&D expenditures have been on an 11-year doubling path, growing faster than total global economic output. While the growth of annual U.S. R&D expenditures averaged around 6 percent, China, for example, has invested in R&D at an annual growth of over 22 percent during the same period of time.[1]

Most recently, Norman Augustine, former CEO of Lockheed Martin, released a follow-up to "The Gathering Storm" report entitled, "Is America Falling Off the Flat Earth?" His message is clear: "Unless substantial investments are made to the engine of innovation – basic scientific research and development – the current generation may be the first in our country's history to leave their children and grandchildren a lower sustained standard of living."[2]

For sixty years, NSF has been a steward of the nation's science and engineering enterprise. NSF investments in discovery, learning, and innovation have been important to increasing America's economic strength, global competitiveness, national security and overall quality of life.

With its relatively small size, NSF delivers an enormous "bang for the buck" of federal government research and development (R&D) investment. NSF represents just four percent of the total federal budget for research and development, but accounts for over sixty percent of non-life science basic research at academic institutions. NSF is the research funding lifeline for many fields and emerging interdisciplinary areas at the frontiers of discovery. In fact, NSF is the only federal agency that supports all fields of basic science and engineering research.

NSF-funded research is characterized by its breadth. NSF prioritizes the integration of education into its research programs, and takes into account the broader societal impacts of the work it funds, such as the training that students and young researchers receive in the research process, and the educational opportunities the work and its people can then provide to the larger community of K-16 students and teachers and the general public.

NSF's comprehensive and flexible support of meritorious projects with broad societal impacts enables the Foundation to identify and foster both fundamental and transformative discoveries within and among fields of inquiry. NSF has the latitude to support emerging fields, high-risk ideas, interdisciplinary collaborations, and research that pushes, and even transforms, the very frontiers of knowledge. In these ways, NSF's discoveries inspire the American public—and the world.

NSF's organization mirrors science and engineering. Its portfolio spans the biological sciences, computer and information science and engineering, engineering, geosciences, mathematics and physical sciences, and social, behavioral, and economic sciences – encompassing both research

[1] http://www.nsf.gov/statistics/digest10/global.cfm#4

[2] Augustine, Norman. Is America Falling off the Flat Earth? National Academies Press

and education in these areas. NSF also carries out specific national responsibilities for polar programs cyberinfrastructure, international science and engineering, and a range of responsibilities related to the nation's overall capabilities in science and engineering, including statistical resources on the overall U.S. and international R&D enterprise. The 25-member National Science Board sets the overall policies of the Foundation.

The cornerstone of NSF is the merit-based, competitive process that fosters the highest standards of excellence and accountability – standards that have been emulated at funding agencies around the world.

2011 Budget Request Highlights

At NSF, we understand that new discoveries are a driving force behind societal progress. As the nation's premier funding agency for basic research, our mission is to advance the frontiers of knowledge, where high-risk, high-reward research can lay the foundation for revolutionary technologies and tackle complex societal problems. The NSF budget for 2011 reflects this vital agenda, and I'm pleased to present it to you today.

Let me begin with the big picture. As noted earlier, the President is requesting $7.42 billion for the NSF in FY 2011. That's an increase of almost $552 million, or 8 percent above the current 2010 appropriated amount. While it seems like a large increase, this level is necessary to fulfill the President's vision for doubling the National Science Foundation's budget. This increased investment will reinforce NSF's leadership in basic science and engineering and allow us to preserve America's preeminence in the global technology economy.

In this year's proposed budget, funding levels increase for every NSF appropriations account. Research and Related Activities investments increase by 8.2 percent, and our Education and Human Resources account is increased by 2.2 percent. We need rapid progress in these areas to stimulate the discoveries in research we need to maintain our standing in the global marketplace, and to keep our students engaged and ready to perform in the global workforce. Our budget includes increases for every Directorate and Office within NSF. But, as with any budget, the FY 2011 Request reflects tough choices and clear priorities. It recognizes NSF's unique national responsibility for supporting basic research, our catalytic role in education, and the ongoing need for investments in stewardship.

Here are highlights of some of the key investments we are emphasizing in our 2011 budget.

NATIONAL INNOVATION STRATEGY

NSF's contribution to the Administrations' Innovation Strategy stems from its longstanding role in strengthening the building blocks of American innovation. This begins with investing in fundamental research and educating the next generation of scientists and engineers. It also includes more focused research on topics that advance vital capabilities – such as sustainability, secure networks, and leading-edge technologies – and fostering and facilitating partnerships that reach across today's global innovation enterprises.

Maintain American Leadership in Fundamental Research. Since innovation depends on the foundation of earlier investments, NSF's foremost responsibility in innovation is to continue to support fundamental research and education in all fields of science and engineering. The President's Plan for Science and Innovation aims to double the federal investment in basic research agencies over FY 2006 levels. This investment will be vital to the effort to increase national R&D investments to 3 percent of Gross Domestic Product.

Educate the Next Generation with 21st Century Knowledge and Skills While Creating a World-Class Workforce. Two NSF programs described in this Request support the Strategy's educational goals.

- **The Graduate Research Fellowship (GRF)** program, (16.4 percent increase to $158.24 million); an Administration priority, supports the development of the Nation's future scientists and engineers. FY 2009 marked the beginning of a growth trajectory to triple the number of new awards made each year to 3,000 by FY 2013.
- **RE-gaining our ENERGY Science and Engineering Edge (RE-ENERGYSE)**, ($19.37 million) is located at the intersection of energy, environment, and human factors. It is a partnership between the Department of Energy (DOE) and the National Science Foundation that will help the nation regain its leadership position in science and engineering by attracting and educating future scientists in the clean energy field. By 2015, RE-ENERGYSE would prepare up to 8,500 highly educated young scientists and engineers for clean energy careers and provide training for thousands of skilled clean energy technicians.

Support Research for Next-Generation Information and Communications Technology, and Secure Cyberspace. While nobody can predict which of today's fundamental discoveries will become tomorrow's new products and processes, a number of NSF programs support the Strategy's goal to promote innovation. These include:

- **Science and Engineering Beyond Moore's Law (SEBML)**, (50.3 percent increase to $70.18 million). In 10 to 20 years, current silicon technology will reach the limits of Moore's Law – the empirical observation that computing power doubles roughly every 18 months. SEBML's transformational activities accelerate innovation and create partnering opportunities with the private sector and national laboratories.
- **Cyber-enabled Discovery and Innovation (CDI)**, (2.8 percent increase to $105.48 million) CDI supports transformative, multidisciplinary science and engineering research made possible by innovations and advances in computational concepts, methods, models, algorithms, and tools. CDI breakthroughs advance one or more of the three themes: From Data to Knowledge; Understanding Complexity in Natural, Built, and Social Systems; Building Virtual Organizations.
- **Cybersecurity**, (10.6 percent increase to $144.55 million). NSF's basic research into usability, theoretical foundations, and privacy supports the aims of the Comprehensive National Cybersecurity Initiative.

Encourage High-Growth and Innovation-Based Entrepreneurship, and Create Competitive Communities By Promoting Regional Innovation Clusters

Partnerships for Innovation (PFI), (108.8 percent increase to $19.19 million). PFI brings together colleges, universities, state and local governments, private sector firms, and nonprofit organizations. In FY 2011, $12.0 million will be invested in a new "NSF Innovation Ecosystem" component, which aims to: increase the engagement of faculty and students across all disciplines in the innovation and entrepreneurship process; increase the impact of the most promising university innovations through commercialization, industry alliances, and start-up formulation; and develop a regional community that supports the "innovation ecosystem" around the university.

Grant Opportunities for Academic Liaison with Industry (GOALI), (0.4 percent increase to $18.58 million). GOALI seeks to increase partnerships between the academic and industrial communities and provide opportunities to accelerate innovation by strengthening the discovery knowledge base for a quicker translation of discovery to societal benefit. The program leverages its budget with support from other NSF academic research programs by a factor of four to one.

Centers programs, (8.9 percent increase to $313.78 million). NSF supports over 100 centers in seven interdisciplinary program areas. Centers exploit opportunities in science, engineering, and technology in which the complexity of the research problem or the resources needed to solve the problem require the advantages of scope, scale, duration, equipment, facilities, and students. Centers often leverage their activities through partnerships with academic institutions, national laboratories, industrial organizations, and/or other public/private entities, and via international collaborations, as appropriate.

LEARNING AND WORKFORCE DEVELOPMENT

For America to continue to lead the world in science and technology innovation, it must have the most knowledgeable and skilled science, technology, engineering, and mathematics (STEM) workers in the world. The National Innovation Strategy includes programs that support scientists and engineers at the beginning of their careers, prepare the next generation of Americans to understand and meet environmental challenges, and educate the next generation with 21st century knowledge and skills while creating a world-class workforce.

Administration Priority Programs

The FY 2011 budget maintains strong levels of support for four key Administration priority programs which were strongly supported in the FY 2010 Budget Request. The Graduate Research Fellowship (GRF) Program and the Faculty Early Career Development Program (CAREER) support the most promising students and early-career researchers in order to cultivate the next generation of STEM knowledge workers. Climate Change Education (CCE) targets learning at all levels and is designed to develop the next generation of skilled, educated, and climate-savvy Americans. Advanced Technological Education (ATE) supports new and enhanced two-year college programs that educate technicians for the high-technology workforce.

- **The Graduate Research Fellowship (GRF)** program supports the development of the Nation's future scientists and engineers. As noted earlier, FY 2009 marked the beginning of a growth trajectory to triple the number of new awards made each year to 3,000 by FY 2013.
- **The Faculty Early Career Development Program (CAREER)** develops the future scientific and technical workforce through support of young faculty who are dedicated to integrating the excitement of research with inspired teaching and enthusiastic learning.
- **Climate Change Education** is designed to develop the next generation of skilled, educated, and climate-savvy Americans. It catalyzes activity at the national level in four strands of STEM education: preparation of a climate science professional workforce; public understanding and engagement; resources for learning; and local and national STEM education policy.
- **Advanced Technological Education (ATE)** supports new and enhanced two-year college programs that educate technicians for the high-technology workforce. It is on a growth trajectory begun in FY 2010 to increase the program's funding to $100 million by FY 2013.

Learning and Broadening Participation

The integration of research and education has been a hallmark of NSF since its inception. The Foundation's investments do double duty – generating new knowledge and producing the next generation of scientists, technologists, engineers, mathematicians, and educators. Preparing a STEM workforce ready to lead innovation and address national needs requires the involvement of the full range of talent and diversity in the Nation, specifically students from traditionally underrepresented groups.

The FY 2011 Budget maintains strong support for agency-wide efforts to bring a fuller array of perspectives and participants to advancing discovery and innovation. Investments across NSF seek to broaden participation among people, institutions, and geographical regions.

Comprehensive Broadening Participation of Undergraduate Institutions in STEM (CBP-UI), ($103.10 million). With an FY 2011 investment of $103.10 million, NSF will implement a new consolidated program, which realigns and builds on existing programs: Historically Black Colleges and Universities Undergraduates program (HBCU-UP), Louis Stokes Alliances for Minority Participation (LSAMP), Tribal colleges and universities (TCUP), and Hispanic-serving institutions. This new program's objective is to help build sustainable partnerships and alliances among institutions with strong track records in producing underrepresented STEM graduates, thereby building capacity for the STEM field across a range of institutions. These comprehensive partnerships will increase the institutions' competitiveness by:

- strengthening STEM curricular offerings, enhancing STEM faculty development, and increasing competencies and competitiveness of students
- Transforming infrastructure, operations, and resources
- Increasing support for and engagement in frontier scientific research and access to advanced research instrumentation, and maximizing undergraduate research opportunities
- Facilitating expanded collaboration between scientists and educators at minority-serving institutions with those at majority institutions

- Stimulating innovation and creativity from the nation's education and research enterprise through support of effective collaborations between minority–serving and majority institutions, especially research-intensive universities with NSF Science and Technology Centers (STC), Materials Research Science and Engineering Centers (MRSEC), and Engineering Research Centers (ERC).

Experimental Program to Stimulate Competitive Research (EPSCoR), (4.9 percent increase to $154.36 million) NSF remains a leader in efforts to broaden participation in science and engineering in all states and regions. EPSCoR's goal is to stimulate sustainable improvements in research participation from institutions in geographical areas that are underrepresented in NSF activities. Strategies include supporting research infrastructure improvement, co-funding of disciplinary and interdisciplinary research, and conducting outreach and workshops. This growth mirrors the overall growth for the R&RA account for FY 2009 through FY 2011.

Government-wide Strategy for STEM Education. In addition to its support for the programs and priorities already mentioned, NSF is actively engaged as a leading participant in the coordinated, government-wide strategy for STEM education. NSF is poised to build on previous and emerging collaborations with the U.S. Department of Education, and to use NSF's unique experience and knowledge base in STEM education to identify research and evaluation priorities and to consider appropriate standards of evidence for various stages of research and development cycles. The agencies are embarking jointly on possible collaborations and complementary initiatives to help states improve K-12 student learning in STEM by building and sharing knowledge of effective curricular and instructional practices, and how they can be implemented at scale.

INVESTMENT PORTFOLIOS

A portfolio investment strategy specifically addresses our role in addressing national challenges, such as stimulation of economic growth, promotion of innovative energy technologies which can help mitigate the impact of climate change, training of a world-class STEM workforce, and nurturing a scientifically literate population.

A wide range of ongoing NSF investments contribute directly to energy technologies, understanding and mitigating climate change, and promoting green jobs. The FY 2011 Request presents a new framework for coordinating and enhancing these investments. To leverage NSF's strengths towards addressing the challenges we face, NSF proposes to focus on the full portfolio of activities in two key areas of national importance.

Science, Engineering, and Education for Sustainability (SEES), (16 percent increase to $765.5 million) will integrate NSF's efforts in climate and energy science and engineering to generate the discoveries and capabilities needed to inform societal actions that lead to environmental and economic sustainability. SEES addresses recommendations from the August 2009 report from the National Science Board, *Building A Sustainable Energy Future*, which emphasized systems approaches to research programs, education and workforce development, public awareness and outreach, and the importance of partnerships with other agencies, states, universities, industry, and international organizations.

Cyberlearning Transforming Education (CTE), (63 percent increase to $41.3 million). This new multidisciplinary research program is intended to fully capture the transformative potential of advanced learning technologies across the education enterprise. CTE will enable wholly new avenues of science, technology, engineering, and mathematics (STEM) learning for students and for workforce development. Collaborating with the Department of Education to bring advances in technology to learners at all educational levels will advance the Nation's ability to study the learning process itself.

STEWARDSHIP INVESTMENTS

Since 2001, the number of proposals submitted to NSF has increased by over 50 percent. In that time, staffing has increased by only 19 percent. To support NSF's excellence in science and engineering research and education, NSF must invest in expanding and developing its workforce and resources to maintain a capable and responsive organization.

The FY 2011 Request includes $468.8 million (+$39.1 million) for activities aimed at assuring that NSF will be able to effectively and efficiently manage its operations. Funds will support:

- **Staff,** 40 additional full-time equivalents (for a total of 1,350 FTE) and eleven additional IPAs are requested;
- **IT investments,** such as the expansion of Research.gov, modernization of the NSF financial system, and improvements in the reliability and security of NSF's operational IT systems; and
- **Acquisition,** ($2.0 million). This increase is part of the government-wide effort to strengthen the acquisition workforce. A key priority for NSF is improving capabilities in the pre-solicitation phase of major acquisitions.

A specific emphasis in FY 2011 is promoting strong, independent evaluation that can inform policy decisions, program management, and performance assessment across NSF. NSF participates in the Administration's government-wide initiative to strengthen program evaluation and performance measurement, and shares its commitment to post the status and findings of this and other important publicly available evaluations online.

- **High-Priority Performance Goal:** NSF's goal for the end of FY 2011 is to develop evaluation and assessment systems for STEM education and workforce programs that can provide findings leading to program re-design or consolidation.
- **Foundation-wide planning, analysis, and evaluation.** $1.0 million will support additional staff and associated resources for the establishment of a centralized NSF capability for assessment and evaluation. This would bring greater attention and analysis to such areas as comparing different types of programmatic investments and identifying the most effective means for continuous improvement across the NSF portfolio.

Concluding Remarks

Mr. Chairman, I've touched on just a handful of programs found in NSF's diverse and vibrant portfolio. NSF's research and education activities support the nation's innovation enterprise. America's present and future strength, prosperity and global preeminence depend directly on fundamental research. This is not merely rhetoric; the scientific and economic record of the past 30 years is proof that an investment in R&D is an investment in a secure future.

NSF may not be the largest agency that funds science and engineering research, but our size serves to keep us nimble. Our portfolio is continually evolving as we identify and pursue new research at the frontiers of knowledge. An essential part of our mission is to constantly re-think old categories and traditional perspectives. This ability is more important than ever, as conventional boundaries constantly shift and disappear – boundaries between nations, between disciplines, between science and engineering, and between what is basic and what is applied. NSF, with its mandate to support all fields of science and engineering, is uniquely positioned to meet the needs of researchers exploring human knowledge at these interfaces, whether we're organizing interdisciplinary conferences, enabling cyber-sharing of data and information, or encouraging new collaborations and partnerships across disciplinary and national borders. No other government agency comes close to our flexibility in STEM education and basic research.

In today's high-tech economy, the supply of new jobs is inextricably linked to the health of the nation's innovation endeavor. NSF is involved in all aspects of innovation; NSF not only funds the discoveries that directly become the innovations of tomorrow, we also fund discoveries that lead to still more discoveries that lead to the innovations of tomorrow, and, perhaps most critically, we train the technologists who dream up the discoveries that lead to the discoveries and innovations of tomorrow.

Industry continues to rely upon government support for high-risk, high-reward basic research. It is no accident that our country's most productive and competitive industries are those that benefited the most from sustained federal investments in R&D – including computers and communications, semiconductors, biotechnology, and aerospace.

As we look to the century ahead of us, we face the reality that the other nations in this world are eager to create jobs and robust economies for their citizens. In this context, "globalization" is shorthand for a complex, permanent, and challenging environment that calls for sustainable, long-term responses, not just short-term fixes.

Despite some of the more pessimistic forecasts of some observers, I believe that America can continue to be on the leading edge of ideas and research. Through strong federal leadership, we can maintain the standing of our businesses and universities. We must not only maintain our position, we must actively seek to increase our strengths: leadership in fundamental discovery, including high-risk, high-reward transformational research, state-of-the-art facilities and infrastructure, and a world-class S&E workforce. With a firm commitment to these fundamental building blocks of our high-tech economy, we can solidify America's role as the world leader in innovation.

Mr. Chairman and members of the Committee, I hope that this brief overview has given you a taste of just how very important the National Science Foundation and its activities are to the future prosperity of the United States. I look forward to working with you in months ahead, and I am happy to answer any questions you may have.

EDUCATION AND HUMAN RESOURCES ACCOUNT FUNDING REQUEST

Mr. MOLLOHAN. Well over the past nine years several chairman, several ranking, Mr. Wolf in both positions and myself on both positions, and Mr. Serrano I think was in there at a time, Mr. Rogers probably during that time, I know just talking with all of them offline they all hold you in such high regard, and so it has been easy to support you over nine years.

Dr. BEMENT. And I appreciate hearing that.

Mr. MOLLOHAN. Yeah. And so we thank you for your service again.

Well you suggest that NSF's budget request is eight percent above the amount appropriated in 2010, I think that was your testimony, and the research and related activities increase. What is the research and related activities increase?

Dr. BEMENT. It is about eight percent.

Mr. MOLLOHAN. See we have it at 7.1. I think we have the overall at 7.2. I understand the difference in those two numbers, but what I am curious about is why the education and human resources increase is only 2.2, or that is the way we are computing it, but significantly less than the overall increase, and the increase for total NASA spending on STEM education is by our reckoning 2.3 percent.

Dr. BEMENT. I think the primary reason is again the importance of the National Science Foundation to the National Innovation Strategy. And clearly the budget was skewed to deal with economic forces, putting more money into fundamental research.

Again, major programs that encourage high growth and innovation enterprise, entrepreneurship. Learning and workforce development is an important part of that, and there clearly are three principal objectives in the National Innovation Strategy.

One is to increase the number of graduate research fellowships, to provide more support for young investigators, especially through career grants, to——

Mr. MOLLOHAN. So that is all out. So you are explaining to me why there is only 2.2 percentage increase in education and human resources and only a 2.3 percent for STEM education. Is that what you are after?

Dr. BEMENT. Well that is not the full story.

Mr. MOLLOHAN. That is my question.

Dr. BEMENT. You are asking a comparative analysis why there is more money in R&RA than there is in EHR.

Mr. MOLLOHAN. Correct.

LEVERAGING EDUCATION FUNDING ACROSS NSF

Dr. BEMENT. And I am saying that the NIS priority of the President, the Administration's priority, skewed more of the resources into the R&RA account for the reasons that I mentioned.

On the other hand, I have to say that the EHR account is very highly leveraged within the Foundation. For example, the total funding for STEM education is $1.225 billion, which is a substantial investment. Thirty percent of that investment comes from the R&RA account, and those investments deal largely with undergraduate education and graduate education, but a significant amount also contributes to K to 12 education.

Now that is a conservative estimate. It doesn't include investments that are made by the individual investigators themselves through Broader Impacts, and a lot of the innovative initiatives in developing instructional materials, and also inquiry-based learning, comes out of the research program through the Border Impacts account. There is no way to sum that up very readily, but it is an additional contribution.

I could give you other examples. Another factor is that we increased the base of several important EHR programs in the 2010 budget. One example is the ATE Program, the Advanced Technological Education Program, which deals with community colleges. We increased the base of that program in the 2010 budget by 23 percent primarily because it was a major priority of the Administration.

By increasing that base in 2010 we also increased the fraction of the total funding that would be available for new awards. That flexibility carries over into 2011, so we left it flat funded in 2011 because we had the additional flexibility.

So just looking at one year numbers doesn't really indicate what the pattern might be over two or three budget cycles.

Another example is the ARRA funding that went into EHR primarily for the Noyce Program and the Math and Science Partnership Program. That was $85 million through ARRA funding. All that money was put out in standard grants that will be spent out over a period of three to five years, let us say an average of four years. If you put that against the base for K to 12 education, which those two programs support as far as teacher training, pre-service and in-service training, that is an addition of about eight percent per year to the budget for K to 12 education. And then if you add in the R&RA component, plus the two and a half percent average for EHR, that brings it up close to 10 to 11 percent effective increase in budget.

We also have to pay attention to sustaining renewals of the ARRA funding, so we look at it over several budget cycles to determine what will be the impact in 2012, 2013, and so forth.

So we feel that the 2011 budget for EHR does two things. Number one, it hits all the priorities of the Administration in graduate research fellowships, in the ATE Program and a couple other programs. It also provides funding flexibility for a number of programs that are very important for teacher education.

That is what I meant in my opening remarks by saying the program is balanced. And it is also very highly leveraged.

Mr. MOLLOHAN. So this is your work up, this is your recommendation to the Administration, the funding increases in education, human resources, and the spending on STEM?

Dr. BEMENT. Much of the decision making in terms of which programs to plus up and which ones to hold constant and the impacts of the ARRA funding were decisions that I made.

Mr. MOLLOHAN. How to manage that amongst those accounts?

Dr. BEMENT. Yes.

Mr. MOLLOHAN. What about the absolute request number, is that your recommendation to OMB or is this a result of push back and forth?

Dr. BEMENT. Well the early President's plan for 2011 was a much smaller number than we ended up with. The EHR component stayed pretty much the same as was planned, but the R&RA account was actually substantially enriched as a result of the National Innovation Strategy. So much more money went into research.

Mr. MOLLOHAN. Okay. But my question was for these accounts that I am asking you about, this human resources and the STEM education, did you request more to OMB, and the answer sort of suggests you did.

Dr. BEMENT. Well that is a pre-decisional question, of course.

Mr. MOLLOHAN. Okay. So I am looking for a pre-decisional answer.

Dr. BEMENT. I know I have been in this trap before.

Mr. MOLLOHAN. Well, you know, it is not a trap. You know, it is interesting why that should be a secret. And I am not sure in this Administration it is, but I guess I will just ask that question. Has OMB told you not to answer those questions under this Administration?

Dr. BEMENT. No, this has been a practice a long time. The last time I was, as you recall, stymied by that question was during the Bush Administration, the first term.

Mr. MOLLOHAN. Well then I can understand why you were stymied in the Bush Administration. I am asking you has that policy changed in this Administration or is it consistent?

Dr. BEMENT. Hasn't changed. Hasn't changed.

Mr. MOLLOHAN. So OMB is directing you not to answer these pre-decisional questions as you call them——

Dr. BEMENT. That is correct.

Mr. MOLLOHAN. [continuing]. Before the Appropriation's Committee of the United States Congress? So you won't answer that?

Dr. BEMENT. Obviously as a director of an agency I ask for a lot more money than I actually get, so you can draw your own conclusions from that.

You know, it is just like the President's budget. The President proposes and the Congress disposes.

Mr. MOLLOHAN. I have heard that before.

Dr. BEMENT. Yes, I am sure you have.

Mr. MOLLOHAN. Okay. Well let me ask you this in a more serious vain. When you look at NSF and its role with regard to education——

Dr. BEMENT. Yes.

ROLE OF NSF IN SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS EDUCATION

Mr. MOLLOHAN [continuing]. STEM education, tell us what is the role that you think the National Science Foundation, and it is almost at the philosophy level or certainly at the policy level, what role do you think the National Science Foundation can play, should play, and apply its scarce resources to?

Dr. BEMENT. First of all we invest money in research and development to develop best practices, but also to innovate . . . find innovative ways to not only enhance learning, but also to enhance teaching, and to bring learning and teaching together.

We try to focus on quality in education, but again, our focus is on math and science education, and as a federal agency with limited resources we have to stay focused, and so we leverage our resources with the Department of Education which deals with states in their formula grants, and we expect that once we develop best practice that the Department of Education will work with us, as they do, in translating that—or transitioning that to broader use across many school districts and scaling it up across the country. And that has been the essence of our partnership as long as I have been in the Foundation.

Now, I can tell you a story that I think will illuminate the point. We run the Teacher's Presidential Award Programs for both math and science teachers at both the elementary and secondary levels, and every time they come to Washington, I would say 100 teachers, I ask them a simple question. I have asked this in front of congressmen and congresswomen, and it is always a challenge because I never know how they are going to answer. I ask them how many of you have been impacted by NSF investment in education? And every hand goes up invariably.

So this time I asked them why we have such an impact considering the scale of our program? Their answer was that they work in the trenches every day, and in many cases they have to struggle within their own social environment within a school in terms of what to teach and how to teach and how much latitude they will have to teach.

And almost invariably when that argument ensues if they can cite evidence, evidence-based results of something the NSF supported or funded and cite that as a case they almost invariably win their argument. They appreciate that more than anyone can say, even though we don't fund them directly. We fund the universities, but the impact does filter down, and so that gives me a good feeling. And these are the best of the best, these are the cream.

So hopefully next time when you have one come to town you will have a chance to ask that question and see what they say.

COLLABORATION WITH THE DEPARTMENT OF EDUCATION

Mr. MOLLOHAN. I had one visit me this year. I think I do every year actually, almost every year.

With what office or department or person at the Department of Education do you interface?

Dr. BEMENT. Well we interface at every level. First of all at the highest level I think it is Michael Lach in the Secretary's office. There is an ongoing dialogue between Michael Lach and Dr. Marrett. They meet periodically and they meet for the purpose of identifying areas where there can be more cooperation.

We also operate at the division level. We have a close working relationship with the Institute of Education Sciences. In fact we have two joint programs with them in assessment. First of all assessing professional development of math teachers, and then assessing professional development in science across the board, STEM across the board. But even these we are always looking for new opportunities.

At the program level we have very close working relationships. For example, in the Math and Science Partnership program we sponsor joint workshops, we meet with state officials. We are part of each other's websites. And more than that we strategize how to do the transition and also the scaling at the state level.

So today about 60 to 69 percent of the MSP projects that are closely linked with state initiatives. These are NSF projects that are closely linked with statewide initiatives, which is a pretty high fraction.

So I think that relationship has been effective, it is getting better all the time, and the reason for that is that Secretary Duncan and many of his associates in the Department of Education come from the Chicago school district, and the Chicago school district is exemplary because they have used NSF funded programs within their various initiatives to improve science and mathematics proficiency in the grades from 8th grade on up to secondary education.

We have a very easy way to communicate since we have a lot of common ground based on past experience, and so the relationship is very close.

SCIENCE BOARD SUPPORT FOR THE 2011 NSF REQUEST

Mr. MOLLOHAN. Well good. Doctor, does the Board agree with the relative priorities for funding between STEM research and infrastructure and STEM education? Has the National Science Board, is it their judgment as to relative priorities for funding between——

Dr. BEMENT. Well the Board really doesn't differentiate much in priorities between research and education because the philosophy of the Foundation is to integrate research with education, so they have a mutually supportive relationship.

But I would have to say that in reviewing the budget they did review all of the Administration's priorities and they approved the budget in its totality before it was submitted to the Office of Management and Budget, so they stand behind the budget.

Mr. MOLLOHAN. Okay. Thank you, Doctor.

Mr. Wolf.

STATE OF U.S. INVESTMENT IN SCIENCE AND ENGINEERING RESEARCH AND DEVELOPMENT

Mr. WOLF. Thank you, Mr. Chairman.

Just looking at this brochure, Key Science and Engineering Indicators, on page 14 it shows the location and estimate of worldwide R&D has moved from North America and Europe to Asia. You said the distribution of R&D expenditures has shifted from 1996 to 2007, Asia's shares has risen to nearly one-third due to mostly by China's rapid R&D. The average annual growth rated number researchers you look at that chart B, U.S. is flat, EU, flat, Russia down, South Korea dramatically up, Taiwan even more, China much more, and Singapore even much more than that.

With this information and what I asked you at the outset and knowing that 50 percent of the money that was allocated last year roughly for STEM was accessed, and looking at where we are on the math and science scores, where do you think we are now as a Nation, vis-a-vis, China manufacturing, education?

And you know one of the questions you know I am going to ask you is on the language that we put in for the study that we asked you to do. So where do you think we really on now?

At one time you had told me that Europe was making an effort to bring people back to Europe to work in their universities. And so just kind of in a couple minutes tell us where you think we really are at this time.

Dr. BEMENT. We are going through a period of rapid change and we are being challenged in terms of our position in science and technology more so than ever before.

Our world share, even though we are still the dominant research performer in the world today, and our universities are ranked very highly and are highly regarded, one has to recognize that almost every nation in the world recognizes that in a knowledge economy, economic growth in prosperity, are to a large extent, dependent on investment in education, investment in research, and investment in infrastructure. So they have been investing very highly.

In Europe, Germany, and the UK and other countries are trying to improve their relative ranking of their universities because they don't rank as high as they feel they should. The same thing is happening in the Far East.

For example, KAIST—I was in KAIST just three or four weeks ago—KAIST is a Korean Advanced Institute of Science and Technology, it is sort of the MIT in South Korea. They have come from a position way down to a position where they are now ranked 12th in the world in engineering, and there are only three institutions in the United States that rank higher than they do, Cal-Tech, MIT, and Cal-Berkeley, which indicates where they stand relative to a lot of other universities in the U.S. as far as international ranking is concerned.

So the world share of research and development of the U.S. has gone down not so much that the absolute numbers have gone down, the absolute numbers do continue to go up, it is that everyone is investing so much more.

For example, our investment rate in federal funding has been increasing about six percent per year across the board roughly. In China it has been increasing 20 percent a year. In most of the other Asian nations it has been increasing at least ten percent a year. Well those kind of increases over time will make a difference.

And for example, in China data that go back to even 2007 indicated that the total number of researchers in China equaled a number of researchers in the U.S., and I am sure today they have more researchers in China than we have in the U.S.

If you look at advanced technology, we aspire to push forward clean renewable energy, nuclear energy, bio derived hydrocarbon fuels, and wind energy. Well guess where the world's share of the technology, the equipment and the facilities and the displays and so forth are going to come from? At the rate we are going, we will be buying our nuclear reactors from South Korea, we will be buying most of our wind generators and photovoltaic panels from China. We are already purchasing some bio derived fields from Brazil.

So that these changes are primarily about national will, it is not necessarily changes due to capacity or capability, it is national will. They want to be leaders, they want to set the standards, they don't want to be dependent on the rest of the world for standards, and they are succeeding.

So that is going back to your earlier question, that is what keeps me awake sometimes at night.

INTERNATIONAL COLLABORATION

Mr. WOLF. Well then I guess to follow the question would be this: If the trend continues where it is now both here in the United States and in Asia and other places, what do you foresee the circumstances if this same question were asked of the director of the National Science Foundation 20 years from now? What do you think their answer will be as to where we are? What impact do you think this will have?

Dr. BEMENT. Well if I could have the luxury of projecting myself ahead 20 years and then answer that in retrospect.

I think the point is, and this is why I put so much emphasis on international collaboration. This is the way of the world, it is not a "king of the mountain" approach anymore, it is no longer a matter that the U.S. is going to be dominant in all fields of science anymore in the future. We will be dominant in some fields, but not every field, not every important field.

So it is imperative that we develop links, we network, we have relationships with top scientists throughout the world. We have to learn how to collaborate in order to compete. We have to know where the frontier is, and the frontier may look differently in China and may look differently in France than it looks in the U.S. They may be seeing different opportunities. If we are not connected, if we are not networked, and we don't have frequent exchange, then we are going to get blind sided. And blind sided means that we won't have an opportunity to move into fast moving markets as a leader. We will be a fast follower or maybe even a slow follower, but we will not necessarily be the leader.

So I put a lot of priority in building up our international programs and the amount of resources we have for international collaboration. We are doing a very good job. We have broadband links with almost every region of the world. Some regions are a little bit dark, but they will be lighted up in the next five years.

So science is being done on a 24 by 7 basis throughout the world, and it is very important that our scientists have an opportunity to succeed in some of the fast moving fields that may be emerging somewhere else. And 20 years from now in retrospect that will be the story.

Mr. WOLF. Well what do you think it is going to be 20 years from now?

Mr. BEMENT. Well, you know, that is not just a science and technology question, that is a political question for the very reason that with information and communication technology the world is shrinking faster now than ever before in the past. We used to think that international travel was a great democratizer or a shrinker of the world. That is no longer the case.

We are going to be interconnected with broadband communication where any person in the world will be able to talk personally with any one other person in the world before too long. We can do it now. In fact, I have international meetings under bilateral agreements with teleconferencing now on a routine basis, and it works. You don't have to travel, you don't lose the time, you don't pay the extra expenses, and you get work done.

We are now entering an era where we can share instrumentation like never before. We can have a researcher in the United States actually operating a piece of equipment somewhere else in the world and getting the data back in real-time. They don't have to have their own instrument.

An example is the ten meter telescope at the South Pole. No more remote region of the world than the South Pole. We have a telescope there that operates during the austral winter, which is summer here, and that is the best viewing season for doing astronomical observation. Well that has been automated to an extent where a researcher, an astronomer here in the U.S. with a laptop can operate the instrument and get the data. They don't have to travel all the way to the South Pole. That is going to be more prevalent.

Furthermore, I think top researchers are going to become more peripatetic, and they are also going to be virtually connected with research groups in several parts of the world. They are very much like orchestra conductors. Orchestra conductors will conductors a symphony in Washington, the next day they will be in London, the next day they may be in Moscow, different orchestras.

I see top scientists doing the same thing with research groups in different parts of the world where they will have an influence, and that will all be virtually connected. They can manage all that in Santa Fe, New Mexico if they wish.

CHINA'S POSITION IN THE WORLD

Mr. WOLF. Well okay. I guess I would comment, you know, I agree with a lot of what you say, probably all.

When I was the chairman of this Committee we reversed the decline in the sciences. It keeps me awake. My wife and I we have five kids, we have 15 grand kids, and I see things taking place and I think I bring a perspective of concern from outside to scientific area.

Norm Augustine came to a group that we had where he made a comment that in the 16th Century Spain was number one, and we know what happened to Spain. In the 17th Century, it was the French century. In the 19th Century it was the British century, you know, the sun never set on the British empire, if you will. And the 20th Century was the American century. And he made the comment that he was concerned that the 21st Century could be the Chinese century.

And I think what troubles me, I get that this institution doesn't seem very troubled by it, and the previous administration didn't seem very troubled by it and this Administration doesn't seem very troubled by it do they? They just don't seem to care.

But if you look at China and their values; the Chinese government. I mean the persecution of the Catholic church. I used to say there were 34 Catholic bishops in jail, I can't say that anymore because some of them were so old they have died. But everyone that was in jail was still in jail, the ones that are out of jail now have died. Nobody says anything, nobody seems to care. That is a value that is not good for the country.

Protestant pastors are being rounded up, thrown in prison. That is bad, that is a value. A government can round up somebody purely preaching the gospel. That is not good.

What they have done to Tibet. I went to Tibet ten years ago, I went with a young Buddhist monk, we went in the monasteries. They have tortured the mild mannered Tibetans. Nobody cares.

This Administration, the President won't even meet with the Dalai Lama the first time he came. They are persecuting the Muslims, the Uighur. The Uighur are going through a very difficult time. They are spying against us. These are cyber attacks. I am sure you have had Chinese cyber attacks against you. They have had cyber attacks against this Congress and they don't really do anything about it.

And so the values—and if you want to take it down to the raw what it means for real people, the number one supporter, the government is China, the genocide in Darfur is Chinese generated. Chinese generated. They sell the bombers, the Kalashnikov's, the Soviet helicopters.

So the world will be a different world from a values point. And so while the Chinese people are wonderful, when they come here they come through my office, I don't worry about the Chinese people, but I worry about the Chinese government.

Dr. BEMENT. Yeah.

Mr. WOLF. And since the Bush Administration and this Administration, China has the worst human rights record than it did ten years ago.

And we see Google. Very few people want to come to the defense of Google. You know I admire the leadership of Google that is willing to speak out.

So the world will be different with China with those values because then they can use it for bad, for evil, for bad things. And so it worries me deeply.

Dr. BEMENT. Well, I don't believe very much at all of what Lenin said, but he did say one thing that I think applies to this situation. His statement was "quantity has a quality of its own", and that is what we are facing is quantity.

EXAMPLES OF EFFECTIVE STEM EDUCATION

Mr. WOLF. The question I wanted to ask you. We put language in asking NSF to convene a panel. We had originally— we were going to put in Norm Augustine's name, but we didn't, we didn't do that. I was a little disappointed that we got a response back from your people saying we have identified the National Research Council Board because we wanted some best practices, and with all the funding they get we believe that you know understand best practices.

The response we got back said that you are going to contract it out, the report will require nine months to complete from the time the award is made, from the time the award is made. The language called for 180 days. So if you can use your bill signing ceremony pen just to tell whoever is responsible we would like to see this kind of pushed up much faster. The bill passed in what, November?

Dr. BEMENT. Yes.

Mr. WOLF. So you have had December, January, February, March, and now we are almost at April. So if you can expedite it and try to get something out quickly, I don't think it is a major B1 Bomber contract, it is something to get the very best information that is around that and kind of pull it together so we can get something. Ideally I would like to see you have something by the beginning of the school year. I think we missed this upcoming school year, so that superintendents around the country and other curriculum people can see what works.

Because you would agree, I assume, that if you lost a young student by 6th grade, the likelihood of getting them back interested in math and science and physics and chemistry is very small; if not impossible. But if we capture them in those early, early years the better opportunity they will have. Because this shows that we are falling behind in that area too.

Dr. BEMENT. I will look into a dual track on this. I think the approach with the National Research Council is a more deliberate approach, but it may be that we do a shorter term approach in parallel. I am going to try and satisfy that.

Mr. MOLLOHAN. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman, and welcome, Dr. Bement.

Dr. BEMENT. Thank you.

INTEGRATING STEM RESEARCH AND EDUCATION ACROSS GOVERNMENT

Mr. HONDA. I read the testimony with a lot of interest, and permeated throughout the testimony was a discussion around how we can improve our research and development, the information, and the knowledge that we have gathered through grant funded research in the area of STEM, and also the discussion about innovation and teaching innovation and inventiveness, and all these things that I think came out in the report that the National Science Board had put out in 2006.

And in 2007 I introduced a bill. Right now it is H.R. 2710, but at that time in 2007 when we put out a bill it was H.R. 6104. H.R. 6104 had laid out basically what the report had asked us to do.

And the other thing that we noticed is that based upon the report it appeared that there were a lot of silos that were not talking to each other in terms of STEM research. Agencies, different agencies had done STEM research. I think the number was—we spent close to $2 billion with 12 agencies and none of the information was being shared with each other where there could be a repository of information and conclusions that could be shared with the education field and other fields. And we shared the Board's concern through that report.

And it appears that again we are rehashing what was said in 2006, we tried in 2007, and again we tried to do it this year under H.R. 2710. We did H.R. 2710 because part of our original bill is taken up by the Science and Technology Committee, so we have taken the rest of it.

Our interest in E–STEM, enhancing STEM education was also—we were also saying that in the Department of Education there should be an office that would be headed by an assistant deputy secretary of education, that you also had a National Science and Technology Council, that within that there should be a full committee that deals with STEM. None of those things have happened, but it sounds like this is what you are suggesting in terms of just out of administrative fiat.

Given that and for sustainability and also assuring this scientific innovative ecosystem, I think you called it ecosystem, would it not be beneficial to put this into statute rather than just have an existing one in the Administration and then not having it sustained throughout the time?

Dr. BEMENT. Well, Mr. Honda, the current activity in the current Administration is to take up this issue based on the American Competitiveness Council activity in the previous administration where they identified all the various programs across the government and to develop a government-wide strategy for STEM education. So I think it is totally faithful with what you are trying to accomplish with the bill.

There is within the National Science and Technology Council a subcommittee on education which is co-chaired.

FIRM DIRECTIVE FOR INTEGRATING STEM RESEARCH AND EDUCATION ACROSS SOCIETY

Mr. HONDA. Right, I understand that, now I am suggesting it goes up to level of committee.

Dr. BEMENT. Well that is up to the director of OSTP.

Mr. HONDA. Well would it have more stature and more impact if you had a committee rather than a subcommittee?

Dr. BEMENT. I am not sure it would be anymore effective. You know, they have got a full platter of work at the present time, and I think they have plenty of support. I am not sure what the next step would amount to.

Mr. HONDA. Well not to be argumentative, they may have a lot of things on their plate, but if all this discussion about integrating the research and the development into various parts of our societies and various parts of our activities in terms of instruction, pre-K to postgraduate, if that is not part of the daily discussion, how you doing, how is it going, it will never get done.

But you know, upon reflection everybody will say that was a good idea, how come we didn't do it? And we are at that point again in 2011, this would be a good idea, now we are getting started, we lost five years. And so putting in a statute where you have an expectation rather than just only, you know, having an expectation to statute at least we can have some guidance and create some benchmarks.

If there were a bill out there like that would that be something that you could sign onto?

Dr. BEMENT. Well, I think what I would like to suggest is that we have people within the Foundation work with your staff to at least inform you what the current pace is and what the current activity and schedules are so you have a general idea.

Mr. HONDA. We have done that, and we would love to do it again. But in terms of——

Dr. BEMENT. But I think what is going on now will have an impact on the next budget cycle, the 2012 budget.

Mr. HONDA. I am sure it will, but I am looking for sustainability. Part of terminology we use in the green vernacular is sustainability, and if we are looking for E–STEM to be imparting enhanced STEM into everything.

The other thing you mention in your report, your testimony, you are suggesting that there should be an integrated approach to other areas, because it does have impact, but there is nothing there——

Dr. BEMENT. Yes, I fully agree with that.

Mr. HONDA. But there is nothing that says thou shalt. There should be some sort of directive or a very stronger statement in that, because we could produce engineers.

My son is an aerospace engineer, and he admits that he is not well rounded, he is kind of lopsided and he can do some of the other stuff, and all this stuff should be embedded in all the other activities it seems to me so that we have a citizenry that at least has the baseline and not be not be, misled by misinformation to the media that, there is no such thing as global warming. At least have an argument with yourself that is, critical and based on some facts.

And I think that is one of the downfalls of our country. We only see one side, and our side is always right whether it is empires or——

Dr. BEMENT. Well, I don't think you could find a better champion for STEM education than the President.

Mr. HONDA. I am not arguing that.

Dr. BEMENT. He is going on record—gone on record many times pushing STEM education.

Mr. HONDA. Dr. Bement, I am not arguing that point. I am just asking would it not be sustainable if we had this embedded in some statute that reflects the President and your—and this report's sense of direction and importance?

Dr. BEMENT. Well, I guess I could only say I am not inimical to it, I just don't—I just can't speak for the Administration on that issue.

Mr. HONDA. Well as an educator it seems to me the public policy and the kinds of things you are talking about that we should be able to do this.

I asked Dr. Augustine the question, can innovation be taught? And he said, well it is very difficult, because it is in the character of each person. And now we are talking about being able to teach inventiveness and innovation if we did it right, and we put something together for NSF to look at that for funding, and hopefully we can revisit that, because as an instructor I think we can do that. All you have to do is look at the walls of a lot of these companies where they have their engineers and scientists with their patents up there, the ones with peaks are the ones you want to study I guess.

But I just wanted to lay that out just so we can have a future discussion with our staffs with your staff.

Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you.

Mr. Serrano.

Mr. SERRANO. Thank you, Mr. Chairman, and thank you for joining us today.

I want to take you to one of my favorite recurring subjects, and that is the observatory in Arecibo, Puerto Rico.

Dr. BEMENT. Yes.

NATIONAL ASTRONOMY AND IONOSPHERE CENTER (ARECIBO)

Mr. SERRANO. And I want to first of all, as you know the plan seems to be to continue to reduce its funding, while they seem to be to want to close it down in the process, and continue to reduce its funding, yet I seem to find in my way of looking at things a contradiction between people who make budget decisions and the scientific community.

There seems to be more and more statements coming forward every so often telling us that there is a need for the work done at the observatory.

Now needless to say in the territory of Puerto Rico this has caused great alarm for many reasons. For the importance they feel it has in the scientific community, the importance it has to the commonwealth of Puerto Rico, you know, in so many ways and we just finished that debate this week, that the territories get treated differently. In this case having placed the observatory there was quite a boost years ago to the relationship between the United States and Puerto Rico. There is an issue of jobs obviously and of tourism where folks go to see it because they know it is advertised as having been in a couple of movies. James Bond has a lot of fans throughout the world and people want to see this observatory.

But any way, first of all, is there a contradiction or is there at least a difference of opinion between folks who want to reduce the budget and eventually close it down and people in the scientific community that say there is an importance and a need for the observatory?

Dr. BEMENT. Well let me state my position. First of all, I have never taken a position of closing it down. The senior review that looked at all the telescopes and all the assets in astronomy made the statement that it continued to do valuable research, and I believe that.

The problem is that it has gotten beyond the capacity or the capability of the Foundation to be the sole supporter of the telescope, so we have been looking for partners. One partner would be NASA, for example. They have the mission of tracking low earth objects such as asteroids and so forth. Arecibo is the ideal instrument for doing that, and it does do so at the present time.

The opportunities in astronomy are still so great in terms of getting back closer to the Big Bang and understanding how the universe began and all the aspects of evolution of the universe. It is still a very compelling topic. So there is always a need to build new telescopes. And we have at the present time substantial investment not only in ALMA, but also a new solar telescope that we wish to build in Hawaii. All those put pressure on the operation and maintenance expenses of our existing telescopes.

Now Puerto Rico has done quite a lot and they have increased investment in Arecibo. So you know the intent is not to just keep drawing down the budget to zero. The point is to find how we can continue to operate Arecibo, but not at its full capability. Other people are going to have to come in and help.

Mr. SERRANO. But there is a recommendation for yet another decrease I believe of $1.6 million less than last year.

Dr. BEMENT. Yes.

Mr. SERRANO. So there is that intent, and my question to you is how successful are we in getting NASA or others to share funding?

Also the projections were made on flat funding for the Foundation. Well that has not been the case in the last couple of years, nor do I think it will be the case in future years.

So you see here is the problem. As I tell many people in a very serious way and half joking for some folks, I represent two districts. I represent the Bronx and I represent the place where I was born, Puerto Rico. And you wonder how much of this has to do with the relationship with the United States. The territories are always last. I mean, I don't want to drag you into another discussion, but you should have seen what we went through in the health care bill just to get the territories something.

Dr. BEMENT. Yes.

Mr. SERRANO. And it wasn't enough that you were talking about American citizens. The fact that they don't have two senators, and you know, in Puerto Rico's case seven members of Congress makes a big difference.

So it will always, unless we make a special effort to save it and to keep it open, Arecibo will disappear because it is not a priority.

In fact when you are telling me you are building a new one in Hawaii I am all for that, but it doesn't hurt to have a president in the White House—I was born in Hawaii, so I suspect that one will do very well.

Dr. BEMENT. Well that was planned well before the election.

Mr. SERRANO. I understand. It just coincides this way, you know. Just like it coincides on my watch.

Mr. BEMENT. Let me clarify one of your issues. I simply needed to bring on additional partners.

Mr. SERRANO. Right.

LONG-TERM FUNDING OF THE NATIONAL ASTRONOMY AND IONSPHERE CENTER (ARECIBO)

Dr. BEMENT. We are also looking within the Foundation for additional partners. For example, one of the capabilities at Arecibo is they're working on atmospheric and geospace sciences, and I have been there and I have seen the facility and they do have a good staff and they do make a major contribution.

So we have got in our Atmospheric and Geospace Sciences Division and they are—in the fiscal year 2010 budget they put in $2.2 million which brought the total up to $10.6 million, and as compared with the 2009 budget of $9.6 so that was an addition of a million over all.

Now the 2011 request it goes back down again, but it is hovering at around $9 to $10 million a year. I don't see that that is inconsistent with my statement that we are trying to maintain.

But I would be more than happy to have another federal agency come in and become a co-supporter of that facility so that it would have a much more robust program.

Mr. SERRANO. All right. Let me just make two quick points here, I don't want to take too much time on this, and at the same time ask you a question.

The original report did recommend closure after 2011 if significant non-federal sources of funding are not found.

Dr. BEMENT. That was made by a senior review panel that did not include officials of the Foundation. I told you my position.

Mr. SERRANO. So officials of the Foundation you are saying for the record are looking for a comfortable level of funding that you can afford, but not intending to close it down?

Dr. BEMENT. That is my position.

Mr. SERRANO. Okay. And is that position shared by others who may be around after you are not there?

Dr. BEMENT. Well that position was taken in fiscal 2007.

Mr. SERRANO. Right.

Dr. BEMENT. It hasn't changed in three budget cycles, I hope it won't change in the future.

Mr. SERRANO. Okay. And lastly, I just want to for the record, Mr. Chairman, remind folks that this past January the National Research Council released a report on near earth asteroids, that is asteroids that have the potential to hit earth, entitled, Defending Planet Earth Near Earth Object Surveys and Hazard Mitigation Strategies. The report outlined the importance of Arecibo, and it says, quote, "Immediate action be taken to ensure the continued operation of the Arecibo observatory at a level sufficient to staff and maintain the facility and that it should be supported." The report in fairness says NASA and NSF.

Dr. BEMENT. That is exactly the point I was making earlier. This is a NASA mission too.

Mr. SERRANO. And the point I am trying to make is which you agree with, that there are folks involved today in scientific research who claim that Arecibo is necessary.

Dr. BEMENT. And I agree with that.

Mr. SERRANO. All right. Okay, thank you, Mr. Chairman.

INQUIRY-BASED EDUCATION

Mr. MOLLOHAN. As I noted, Dr. Bement, in my opening statement, this Subcommittee held a couple of hearings last month focusing on STEM education.

From the testimony it is clear that the effectiveness of the inquiry-based education in STEM education is needed at all levels, but implementation is woefully lacking.

How many and what percentage of colleges and universities receiving NSF funding offer courses that are inquiry-based other than undergraduate research opportunities and graduate thesis preparation?

Dr. BEMENT. Our information is that in almost all the universities that we support there are faculty that effectively use inquiry-based education or promote inquiry-based education. As a matter of fact, many of investigators under Broader Impacts make a significant contribution to inquiry-based education through the type of research that they are doing. But that is the good news.

The bad news is it is not being used enough, especially in undergraduate education. It is being underutilized. We would like to see a much broader application of inquiry-based education and we continue to press for that.

We feel that first of all the evidence is compelling that it not only contributes to understanding concepts, improving problem solving, but it also aids retention, recruitment, and also graduation success, because students have become more interested in the subject if they have an opportunity to either carry on some type of project work or some type of research as part of the learning experience.

Even computational application, use of computers, computer modeling is a good application of inquiry-based learning, and they get a chance to deal with more complex problems than they might otherwise do.

That is the reason why we are stressing the Cyberlearning Transforming Education initiative, the CTE initiative, to bring on more cyber technology into the classroom for inquiry-based education.

That is pretty much the situation as it currently extends. We have made progress, but we have a long way to go.

Mr. MOLLOHAN. At NSF you primarily fund colleges and universities. How can you increase the use of inquiry in the teaching of science in our schools?

Dr. BEMENT. We can build it into our solicitations, and we do in many respects. A lot of our programs focus on inquiry-based education, so those are some of the things that we can do.

Mr. MOLLOHAN. To what extent are you doing that?

Dr. BEMENT. Well, I will ask Dr. Mundy to answer that question. This is Joan Ferrini-Mundy who is the Acting Assistant Director for EHR.

Mr. MOLLOHAN. Well we should have another chair up there if you want to do that. That was very clever. It is not June yet.

Dr. FERRINI-MUNDY. So the question is what are we doing now? There are lots of strategies for improving the use of inquiry methods for improving in general teaching of science that leads to conceptual understanding and that leads to ability to solve complex problems. And so we have various programs that address this.

One is to try to get the faculty themselves to become aware of these methods, to understand them, to try them out in their teaching, and we do that through our Transforming Undergraduate Education in STEM program.

Another is to continue the research about these methods so that we have evidence about their effectiveness, because that helps in their dissemination too. We have other programs that do that.

Helping K through 12 practitioners come into contact with undergraduate faculty is another way to try to spread the word, and we do that through our GK–12 Program as well as our Math and Science Partnership Program.

And then finally we invest in the STEM faculty of tomorrow, during their own graduate preparation, in helping them to understand these methods.

So we work on multiple strategies and continue to promote the ideas through several programs.

Mr. MOLLOHAN. And that is through grant funding?

Dr. FERRINI-MUNDY. Yes.

Mr. MOLLOHAN. And give me an example of a college, university, where that is happening.

Dr. FERRINI-MUNDY. So the University of Colorado Boulder is a place that has a whole program on using undergraduate learning assists in the teaching of physics, I believe, and so the physics faculty who are also involved in that teaching are working together with undergraduate students to try to improve opportunities for physics learning in the classroom. You have a mix of undergraduates, folks from the School of Education who are doing some evaluation and research about the project, and faculty in the sciences coming together to try to improve the opportunities to really understand physics as opposed to learning physics in a rote kind of way.

Mr. MOLLOHAN. And that is at what level? That is at the college level?

Dr. FERRINI-MUNDY. Undergraduate level.

Mr. MOLLOHAN. Undergraduate level.

Dr. FERRINI-MUNDY. Right.

INQUIRY-BASED EDUCATION IN K THROUGH 12 CLASSROOMS

Mr. MOLLOHAN. Okay. And so how does that lay a foundation for migrating inquiry into K through 12?

Dr. FERRINI-MUNDY. Sure. First of all you have the faculty in physics and in the science departments who are those folks who actually teach the future teachers their subject matter contents and so they are getting the chance to see this used and then to try to bring it into their own teaching. And then hopefully some of these undergraduate learning assistants ultimately might consider becoming K through 12 teachers.

Mr. MOLLOHAN. When you say hopefully, what does that mean? Is that what you do once that program is done, then you are hoping something happens after that?

Dr. FERRINI-MUNDY. No, we actually follow—all of our programs have very strong evaluations components, and so we are very interested in particular kinds of outcomes, and a program like that the main outcome is I suspect about the undergraduate students learning of physics. But our programs for teacher preparation are looking at the impacts of our teachers on the instruction in K through 12 classrooms.

Mr. MOLLOHAN. Do your goals go to migrating this or inserting it into the K through 12 undergraduate programs that are inquiry-based?

Dr. FERRINI-MUNDY. Oh, absolutely.

Mr. MOLLOHAN. What initiatives do you have to help facilitate that?

Dr. FERRINI-MUNDY. One of our major programs is the Math and Science Partnership Program which involves STEM undergraduate faculty, as well as K through 12 teachers and leaders, as well as education faculty at universities and colleges, and so by using those combinations of leaders you get the opportunity to really put ideas together that make their way into teacher education programs.

Mr. MOLLOHAN. How do they make their way into teacher education programs?

Dr. FERRINI-MUNDY. Well the people who are working in say an MSP project may have as a partial goal for their work to do some reform of their undergraduate STEM teacher preparation, they might make new courses or create new opportunities for internships in schools or opportunities for connections to industry.

Mr. MOLLOHAN. It doesn't sound very certain, it doesn't sound like it is a piece of that actual strategy forcing a prototype experience that was tested out. And is that occurring, and if so would it be useful, and if not would it be useful?

Dr. FERRINI-MUNDY. All of our programs have a very strong research and development focus, so we ask our PI's to come with a really clear hypothesis about what they are trying to change and why they are—why they believe it is going to make a difference based on the literature, based on best practice and so forth. They implement those ideas and they study them.

The idea is to produce models, which as Dr. Bement has mentioned, then might be scalable by other organizations by connections to the Department of Education.

So that is the major focus of much of our work, to try out, test, refine, and improve models that then are published, are discussed, are circulated, and are disseminated.

Mr. MOLLOHAN. Okay. What I am hearing is that, you know, you are doing education inquiry-based incentivising—incentivising inquiry-based as you are instructing at the undergraduate level research, at the graduate level, that there is—this may go down into the K through 12 where you have some——

Dr. FERRINI-MUNDY. Well some of our programs are K through 12 focused, and so we do a lot—let us say——

Mr. MOLLOHAN. Who are the grantees? I am sorry.

Dr. FERRINI-MUNDY. The grantees are universities working in partnership sometimes with school districts or with non-profits.

Mr. MOLLOHAN. Where is that happening?

Dr. FERRINI-MUNDY. That is the Math and Science Partnership Program.

Mr. MOLLOHAN. But where, give me an example?

Dr. FERRINI-MUNDY. Across the country.

Mr. MOLLOHAN. Colorado? Is the University of Colorado doing this?

Dr. FERRINI-MUNDY. I don't know for sure if there is an MSP in Colorado, but the University of Georgia has one.

EXAMPLES OF INDUSTRY-BASED EDUCATION IN K TO 12 SETTINGS

Mr. MOLLOHAN. Would you identify yourself?

Dr. SEIDEL. Yes, I am Acting Assistant Director for Math and Physical Sciences, but I have examples of exactly what Joan is talking about as a PI at Louisiana State University. I had NSF funding at a center there, before I came to NSF, where we worked, for example with local school districts and had workshops in the summer where we would have teachers and their students from local high schools, in fact across the state, learning how to build a super computer out of PCs—how to build a Beowulf cluster. And the great thing about that is the kids get very excited because they understand PCs and they can build something that becomes a super computer. And their the teachers also get very excited about it and learn how to do this and then they can begin to incorporate this into the class.

When the kids built the computers they brought them back into the classrooms and we donated them to the schools, and then they maintained these small super computers.

Another example is funding from an ESPSCoR program where we involved students using Sony Play Stations, what they use for gaming, but actually they are small super computers themselves. And so we taught them to run things like storm search calculations on them, which is something understood by many kids in Louisiana because of the hurricane phenomenon that come all the time. And so they understand how these are actually super computers.

And then we have had letters from parents saying their children have been turned around and they are very interested now in going onto college when they might not have before.

Mr. MOLLOHAN. Do you think this kind of education ought to be—inquiry-based education ought to be ubiquitous in STEM education across the country?

Dr. SEIDEL. I think there are all kinds of evidence that inquiry-based experiential learning, hands-on kinds of experiences, and concept-based learning, that kind of activity can be driving what goes on in schools across the country.

Mr. MOLLOHAN. Okay.

Dr. SEIDEL. That is a yes.

FULL-SCALE IMPLEMENTATION OF INQUIRY-BASED EDUCATION IN K TO 12

Mr. MOLLOHAN. Thank you for your testimony.

So if members of Congress who have year after year heard that kind of exciting testimony about these methods that if they were employed they would improve whatever standard test you judge that, and you understand that, and that if it were employed throughout the country would change the testimony before us from that of woe is me, we are falling behind to we are really getting it and we are implementing the policies and techniques and strategies in the school system integrated from K up. We are hearing that, but it is the same woe is me testimony the next year, so that that integration has never happened.

And so would you think it reasonable for members after hearing that to wonder why this is not integrated from the highest levels of NSF through education down through kindergarten?

Dr. FERRINI-MUNDY. Absolutely a reasonable question.

If you think about the whole K through 12 system the main drivers are the teachers themselves, what they know, how equipped they are to teach with this kind of material, to teach in this style, and the materials themselves. So the learning tools, the resources are important. NSF invests of course in both areas.

But not to be overlooked piece is the assessments that are used. It is hard to measure some of this.

Mr. MOLLOHAN. Yes but see—let me—just forgive me.

Dr. FERRINI-MUNDY. Sure.

Mr. MOLLOHAN. And explain to me why that is an answer to my question.

What I am trying to get at is I think I could do a fairly superficial job of answering a lot of these questions having asked them a lot and heard them answered, and I said superficial, but the question that doesn't get answered is the question I tried to ask just a second ago.

By what method and does NSF have a role in introducing these techniques not sort of as an experiment, but as an accepted method to be embraced by the educational communities across the country, how does that happen?

Dr. FERRINI-MUNDY. Okay. I think I would go back to what Dr. Bement said about what he heard from the teachers. Dr. Bement is going to comment too.

One way is by the creation of the funding of materials that use these methods that are well tested and have strong evidence behind them so that teachers can then pick them up and use them.

Mr. MOLLOHAN. And that is a piece of it.

Dr. FERRINI-MUNDY. That is a piece of it.

Mr. MOLLOHAN. Materials is a piece of it.

Dr. FERRINI-MUNDY. Teacher preparation and education is a piece of it.

Mr. MOLLOHAN. Teacher preparation, teacher support.

Dr. FERRINI-MUNDY. Yes.

Mr. MOLLOHAN. Superintendent involvement and acceptance.

Dr. FERRINI-MUNDY. School-based support.

Mr. MOLLOHAN. State board of education——

Dr. FERRINI-MUNDY. Yes.

Mr. MOLLOHAN [continuing]. Support and implementation——

Dr. FERRINI-MUNDY. Absolutely.

Mr. MOLLOHAN [continuing]. And direction perhaps.

Dr. FERRINI-MUNDY. And assessment again, if the tests don't measure——

Mr. MOLLOHAN. Okay. Assessments to do it. Integration, teacher retraining at the colleges. The undergraduate being taught inquiry. And you have all these pieces. And are there prototypes to tie all that together in different rural, urban, southern urban, northern urban, western urban environments to see how you can actually integrate that throughout the system?

Dr. FERRINI-MUNDY. So again, this notion of a systemic approach seems right where you tie together——

Mr. MOLLOHAN. I mean would it be NSF's role to run a solicitation to invite different educational systems to be a part of a comprehensive testing out of how you integrate all that, and prove out whether this STEM education works? And the only way you could do it would be if you did it in an integrated sort of way up and down wouldn't it? Would that be an appropriate role for NSF?

Dr. FERRINI-MUNDY. We have had different approaches to that——

Mr. MOLLOHAN. Or have you done it.

Dr. FERRINI-MUNDY [continuing]. Over the years, and we have done it. And I think what we have learned is that it does take all of that integration, but it is costly, because you have to have a lot of partners on board all headed in the same direction and you have to have the policies headed in the same direction, but there have been existence proofs. Our Math and Science—Partnership Program continues those ideas.

And so we are all for these kinds of integrations across all these different parts of the educational system. But to make deep change does take time and does take a lot of collaboration.

Mr. MOLLOHAN. But is that exercise at this point in time appropriate or are you beyond that? You didn't hear my question, you were talking to somebody else weren't you? Or is it useful at this time or are we beyond that?

Dr. BEMENT. Let me butt in, because we have been very hard at work at this, especially in bioscience.

There has been an effort through the last three or four years of the whole community, and in many cases you have got to get community buy in, so this is an approach that involved the community at large. It is now being rolled out. There is a joint program between EHR and the Bioscience Directorate to carry this into implementation. It is primarily focused on undergraduate education in bioscience, but it will also impact K to 12. And if you wish I will develop a report for the record to tell you more about it.

[The information follows:]

Over the past year, the American Association for the Advancement of Science, with support from the National Science Foundation Directorate for Education and Human Resources and Directorate for Biological Sciences, held a series of conversations with faculty, administrators, students, and other stakeholders on the future of undergraduate biology education. The website below outlines the work of this collaboration: the issues, discussions, presentations, and other activities. A summary of recommendations may be found in the report titled Vision and Change—A Call to Action.

The report may be found here: www.visionandchange.org/VC__report.pdf.

Mr. MOLLOHAN. Okay, and I would like you to come up and talk about it, just chat about it.

Dr. FERRINI-MUNDY. Could I add one more thing?

Mr. MOLLOHAN. If you are not doing anything that day you could come too.

COLLABORATION WITH DEPARTMENT OF EDUCATION IN INQUIRY-BASED EDUCATION

Dr. FERRINI-MUNDY. Okay, thank you.

We are in very strong and good collaboration with the Department of Education, and so some of what you are talking about, this kind of systemic approach to how to roll things out in ways that get picked up widely are exactly the topics of our conversations with Michael Lach and others at the department.

That is to say we have even been working on, you know, what is well known about math professional development and how do we immediately then communicate with states with—chief state school officers and with other parts of the enterprise to get these ideas out so that some of the NSF investments get picked up?

So a way we have tried to work on it recently has been through this kind of leveraging of intellectual resources with other agencies that have wider reach where we have been able to build and understand in deep ways the models that can work and then to take them out broadly.

FUNDING FOR INITIATIVES IN INQUIRY-BASED EDUCATION

Mr. MOLLOHAN. Well this is the 2011 budget hearing for NSF, and irrespective of conversations with OMB, and not to get into any pre-decisional secrets here, this would be your opportunity to say gee, if I had my druthers I would like to see something in this area in the 2011 budget request for NSF. Can she answer that, Dr. Bement? Please?

Dr. BEMENT. That is sort of the answer that comes from the initial lead in. If you had additional money in your budget what would you spend it on?

Mr. MOLLOHAN. Well no, honestly it is—you know, if we wanted to do something in this area we would like to know, and have your advice, what would it be? Forget about your budget request. If we wanted to do something in this area, a direction from this Committee, what would your advice be to what we would do? That is a totally appropriate question, I would hope you would answer it.

Dr. BEMENT. I think what you would do is you would move directly to be sure that those programs are well supported.

Part of what we do in order to bring about systemic change is to do innovative institutional integration, and that is taking various programs and integrating them in order to achieve purposes like this, and there is a budget line for that in our budget. And one of the objectives of that program is to also boost inquiry-based learning.

So now that we know the level of interest that you have, there are things that we can do with our existing budget and with our existing programs in order to intensify attention to your interest.

Mr. MOLLOHAN. Well it is not my interest, I don't want to be, you know, I don't have the knowledge base that you have and wouldn't pretend to be an expert.

Dr. BEMENT. But you know based on our testimony that we agree with you fully, so you know, we are not in opposition, we are not talking cross purposes, we fully agree with one another.

Mr. MOLLOHAN. Well we look forward to working on this as we move our budget forward, and thank you, Doctor, thank you so much.

Mr. Wolf.

Mr. WOLF. Thank you, Mr. Chairman.

COOPERATIVE RELATIONSHIP BETWEEN NSF AND SCHOOL DISTRICTS

Following up on one of the Chairman's line of questioning. Has there ever been the opportunity for the NSF to develop a cooperative relationship with the school district whereby you literally, not take over the school district, but you literally—they were willing to turn this over to the NSF, perhaps one in a rural district one in an urban district whereby NSF would run the program?

Dr. BEMENT. Not within the limitations of the Constitution.

Mr. WOLF. No, where they would ask you. School districts would be very open. I mean you mentioned Chicago. You know, if you have a failing school district they may be very open. I am not talking about the federal government taking over, I don't believe that. What I meant is that whereby they would say our math and science scores are not very good, et cetera, et cetera.

Dr. BEMENT. Well, I don't know of a single example of that.

Mr. WOLF. Would you be interested in something like that?

Dr. BEMENT. I don't think so. I don't think we are in the education business per se, I think we are in the education research business, and the investment that we make can have an impact on schools broadly rather than just a single school.

Mr. WOLF. Well, I know that, but the reason we put the language in last year was to get you to give us something that would be best practices that every other school district could use. We don't have that from you now, and if you had a situation where you went into a particular urban, suburban, rural, whatever and did something it would be an——

Dr. BEMENT. Well, we do have pieces of it, Mr. Wolf. We are on the website of the Institute of Education Sciences on best practices. Some of these best practices are on their website. In fact a good fraction of the best practices on their websites are based on NSF programs.

Mr. WOLF. Okay.

Dr. BEMENT. And we can give you that information for the record.

[The information follows:]

The What Works Clearinghouse, Institute of Education Sciences, U.S. Department of Education provides a list of nine topic areas under which reviews of research on important issues in education can be accessed. NSF-funded activities can be found under two of these topic areas:

- Elementary School Math—of the nine interventions reviewed, two have received NSF support.
- Middle School Math—of the fourteen interventions reviewed, five have received NSF support.

The web link to the topical index is www.ies.ed.gov/ncee/wwc/reports.

NSF'S ROLE IN IMPROVING SCIENCE EDUCATION

Mr. WOLF. This year and the last the Committee heard testimony from experts advocating a more prominent leadership role from the NSF in a national effort to improve science education. Your education budget continues to grow, but at a lower rate than your research program.

How do you see NSF's role as distinct with that of the Department of Education, and do you feel that roles and responsibilities in funding are properly aligned?

Dr. BEMENT. Well, I can say categorically that I believe that our programs are effective, I think they are making an impact on improving math and science proficiency. I feel that it is in the interest of the Nation that we continue that role, and we are working very hard to find ways of leveraging our resources to do it better.

Mr. WOLF. But have not the scores continued to drop in comparison to other countries?

Dr. BEMENT. No. Well the latest international data indicates that in 4th and 8th grades math proficiency scores have increased significantly.

Mr. WOLF. What about in high school?

Dr. BEMENT. I am sorry?

Mr. WOLF. How about in high school?

STATE OF K TO 12 SCIENCE EDUCATION IN THE NSF

Dr. BEMENT. I think probably less clear in high school. The problem area is in science. Science has been pretty flat, it has not improved very much.

I believe from what the teachers tell me they feel cheated sometimes in their education programs because they don't get very much exposure to science. Unless they are teaching in secondary schools they don't get focused preparation in science.

Mr. WOLF. Cheated by their school district or cheated by the college?

Dr. BEMENT. I am talking about the colleges. I am talking about the education programs.

Mr. WOLF. The last study that we worked on said that the STEM money in 2007 was only 50 percent of the STEM money was used. Is that accurate?

Dr. BEMENT. I don't know that.

Mr. WOLF. Wouldn't that sort of fit in though if the teachers felt cheated that that would be the no cause and effect death?

Dr. BEMENT. I think it is an issue that has to be taken seriously by schools of education across the board. Under No Child Left Behind science was not a measure. It wasn't a requirement. So in many cases teachers were not encouraged to put a lot of time and effort into science education, and I think that has to change. There has to be much more emphasis on science and it has to start early.

Most children by the time they are eight to ten years old already have a world view, they already know pretty much what they want to be when they grow up. If you don't have an influence, if they don't have basic understanding of some science or at least the scientific method early they are going to have an education deficiency as they try to move up to higher grades.

Mr. WOLF. Well, I think that was why we had asked you to do that study.

There was a full page article in a journal a week ago Saturday I think by Chester Finn and he talked about in China for instance they go to school 41 more days than we do. He also commented on other countries that have Saturday classrooms, Saturday schools. He also commented on the number of hours in different countries.

Does this also have a major impact as far as scores, and I don't want to use the word techniques, but something like that? Because if you take off as he said the full summer the school gets out on June 10th, doesn't go back till the day after Labor Day, the memory loss drops off.

Dr. BEMENT. Well let me give you a case in point in South Korea where I just visited. The concern that the president of South Korea, Mr. Lee has, is that parents are putting too much emphasis and spending too much money on private tutoring for their children. The children have hardly any time of their own. They start school at 8 o'clock in the morning and they go sometimes till 10 o'clock at night, because when they finish the school room part of their learning then they go to a private tutor and they spend another two or three hours with a private tutor.

That kind of learning will give you better proficiency scores on tests because the tests are pretty much what the students are being taught, but a lot of it is learning.

A few years ago I came to realize that education administrators from Singapore were quite concerned because even though they were scoring high in math and science in Singapore, they were finding that their students once they got into higher education were not very creative or not very innovative, and they saw the United States as the country where education and creativity and innovation was the gold standard, and so they wanted to learn from us, and these are the exemplars when you look at just the scores of math and science proficiency. They wanted to learn from us how to teach creativity and innovation.

Which gets me back to inquiry-based learning. It is in inquiry-based learning and activity-based learning that you teach creativity and innovation. That is our strong suit. That is what we ought to build on. So we are in complete agreement on that point. That is the strength of our education system. And unfortunately we are faced with a tyranny of averages as a Nation because we look at means.

One has to recognize that we have the brilliance among our young people in this country that can go to an international math Olympics and come back with gold medals. They can go to a computer software Olympics and come back with gold medals. They can go for a robotics international competition and come back with gold medals. So the talent is here.

Now the challenge is to make education and excellence in education more broadly available, that is where the challenge is.

Mr. MOLLOHAN. Is a part of that mining those high aptitude math and science students, those who have inclinations in this area, identifying them and concentrating on them?

Dr. BEMENT. Well that is being done. Almost every state has their own academy or their own institute for bringing in the very bright students from around the state and putting them into a residence education program where they are taught by faculty that have master's and Ph.D. levels of education. I mean these are almost like mini universities for the most part.

Mr. MOLLOHAN. So the answer is yes, and I didn't want to take up any more of that time, but maybe I will follow up on it.

Mr. Honda.

IMPLEMENTING CREATIVITY AND INNOVATION IN OUR EDUCATIONAL SYSTEM

Mr. HONDA. Thank you, Mr. Chairman.

The discussion is pretty interesting. Just to continue on this line of discussion where you are really promoting and being a champion for teaching innovation and creativity, and yet I don't see where you are going with it except to say that we got the information, but it is up to other people to do it.

A question, and I don't want an answer right now, but the question is then how would you create a process from your point of view to operate with the other entities to have a systemic process where it will be embedded in our public school systems? That is one question.

Then you talked about the tyranny of mediocrity I guess, and then you say but what we have samples——

Dr. BEMENT. No, I didn't mean that, sir, I meant tyranny of averages. In other words we look at the averages and we believe in the averages. You don't see the variability around the mean.

Mr. HONDA. Okay. The tyranny of average then. And I am not quite sure what that tyranny is, maybe you can answer that in part of your answer, then how do you make excellence the predominant effort in our system to make it more available if the information you already hold that speaks to excellence is not shared or advocated by your group with the rest of the community in public education?

Dr. BEMENT. Okay. We have clear examples. We have a program that is designed——

Mr. HONDA. No, I know we got programs.

Dr. BEMENT. Well let me go on.

Mr. HONDA. No, no, I want you to answer the question. How do you see this becoming infused into our system then?

Dr. BEMENT. And that is the question I am trying to answer.

Mr. HONDA. Okay. Because I will stop you if you say we have programs and yet you don't describe how that program works.

Dr. BEMENT. Well they start with programs, but to get to your question, the math and science partnership is primarily designed to bring about systemic change and to improve performance in math and science education. And it goes back to my question of transitioning and also scalability.

In other words, within a state—within your state, Chairman Mollohan, we have the Math and Science Partnership with West Virginia, Kentucky, Southern Ohio. That program has done magnificent work in improving math and science performance.

Now the question, getting to your point, how do you scale that, how do you transition it? You have to work with the states. Because even though this is a national problem and a national issue, the responsibility for education is with the state and local areas, not with the federal government. So unless the state adopts these methods and infuses them in their school systems they are not going to be very effective.

Mr. HONDA. Okay. Mr. Chairman, if I just may insert myself again.

This is based upon the Constitution that the Constitution says the states have a primary responsibility for education. Okay. The Constitution was written on September 17th, 1787, that was the first day of our federal government. They had no departments. And so they said it is going to be the responsibility of the states.

We have developed to a point in 2011 where we could talk to each other in real-time as you have said, shrunk this world to a point where they could never have conceived it at the time they wrote the Constitution.

Is it not time for us to take hold and understand that the span of time that has gone on that we jump to 2011 from the old Constitution and say in spite of that we have to find a way to become partners where what we know and understand should be and somehow convince the public, what we call the local entities, that this is the reason why, and if you can't understand that you complain about other countries, but you have to understand that they are not the enemy.

Dr. BEMENT. Right.

Mr. HONDA. We are the enemy of our own selves.

How do you readjust what it is that you know and understand in the context of what I just described and make it happen?

Dr. BEMENT. Well, Mr. Honda, politics is the art of dealing with values, and what you are raising a question about is how do you deal with values in a contemporary society? That is a political activity that has to be determined as part of the national governance——

Mr. HONDA. Excuse me. Education and the expenditure of our funds for research and development and the knowledge that comes out of it becomes something that we have that we are supposed to be sharing. Is that not a right to have that shared with the rest of our country and rest of our children instead of hiding behind——

Dr. BEMENT. Well, you know, your point is well taken, but you were asking how do we make it happen, and the only way I can respond to how to make it happen is through the political process.

Mr. HONDA. In your experience, and sometimes when we accept the infrastructure that we have right now, if we accepted the old infrastructure we would still be back in the days where we used to use people as slaves and things like that. We have changed. Our infrastructure has changed. Is it not time to look at the public education as if it were a civil right?

Dr. BEMENT. No, I think we have to put education under the microscope and really study it very hard and make these determinations. At what stage do we begin to adopt national standards, for example? That has been an ongoing question for some time. What is the state-federal partnership in education? How do you structure the state-federal partnership? That is another key question that has to be resolved. How do state governors come together to deal with regional systemic initiatives rather than just statewide systemic initiatives?

In Appalachia, for example, that is a regional initiative. It involves four or five different states. They are taking a regional approach. We need more regional approaches. But again, that is part of the political process.

QUESTIONS FOR THE RECORD TO FOLLOW

Mr. HONDA. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Dr. Bement, we have been talking to you here this morning about 12 percent of your budget plus whatever you are spending on education out of research and related activities. It is not that we don't realize you are doing other things, but you are just doing them so well, and so we appreciate that, and we will have questions for the record regarding all that and some follow up questions along these lines.

Dr. BEMENT. I would be pleased to respond.

Mr. MOLLOHAN. I would appreciate that. And I hope that we can find some time to sit down and visit with you.

Dr. BEMENT. I will get that on my calendar.

Mr. MOLLOHAN. Yes. Have a cup of coffee and talk about this and think about ways that we can help do what you think that we should do in this area.

So again, thank you for your testimony here today. Let me repeat what a pleasure it has been for me to work with you during a lot of those—well all those years actually, I have been on the committee one way or another during that time, and wish you well in your future endeavors, which I know will be as successful and as impressive as your career up to this point.

Dr. BEMENT. I hope our paths will cross many times in many ways.

Mr. MOLLOHAN. Well, I hope so, that would be great.

Mr. HONDA. Mr. Chairman?

Mr. MOLLOHAN. I would certainly benefit from that.

Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman.

Let me just say that I apologize for being what may be considered unkind and unprofessional. I recognize that you are an independent agency, but I think of all the kids across this country, and we are sitting here cogitating intellectually about what they go through every day, and I know that you think about that, too.

Dr. BEMENT. Yes, we have a shared passion.

Mr. HONDA. Right. And so if the only currency our youngsters go to school with is time, and every day that we talk about things that should be, that could be, that isn't, then that is the investment that we lose from them and they get nothing out of it. And if we don't start strengthening our systems and pointing out where some of the gaps are and suggesting how to fill those gaps on behalf of the children then I don't think we have done our work.

But it wasn't directed to you personally.

Dr. BEMENT. I didn't take it that way.

Mr. HONDA. I just wanted to squeeze something out of this hour, but I apologize if I offended you.

Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Honda. Looks like I was premature in ending the hearing. I hope you haven't already readjusted. Mr. Wolf has some other questions.

ICE BREAKER FUNDING

Mr. WOLF. Thank you, Mr. Chairman. One question and one sort of thought.

But the fiscal year 2010 bill transferred funding for the operation of coast guards pulled the ice breaking vessels back to the Coast Guard. It is an initiative we have been involved in for years. Your fiscal year 2011 budget again requested funding on their NSF. Why is that?

Dr. BEMENT. It was our expectation that based on legislation that we would find the Coast Guard putting money into the operation of maintenance of the Polar Sea and also—what was the other vessel? And the Healy.

And so we were all primed to go into the new mode of our operation of paying incremental costs and had thought about our MOU with the Coast Guard in those terms; however, we discovered that the Coast Guard didn't put money in their budget for the operation or maintenance of those ships. And since they are essential not only for science funded by the Science Foundation, but also NASA and NOAA, we felt that we had to preserve the availability of those vessels so we put it in our budget.

Mr. WOLF. Because you would rather it be the other way, but since it wasn't you——

Dr. BEMENT. That is right. It was a default decision.

Mr. WOLF. Okay. Well the other question I want to ask you is there a benefit to NSF of having the funds appropriated to NSF rather than to the Coast Guard? Then the answer would be it should have been the other way, but I understand.

STATE OF SCHOOLS

Dr. BEMENT. Yes. That is the answer.

Mr. WOLF. I guess the last thing I wanted to say. Once, again thank you for your service to our country.

I think the concern that I have is that it just doesn't seem to be working as well as it should.

And you mentioned the Chicago schools. Well the Chicago schools have the highest death rate of any school system. They have been gunning kids down left and right, Chicago. And I saw this Administration, I saw, you know, the Secretary moved to Arlington County, which I represented, because he wanted a good school for his kids.

Last week I went to a school in the inner city, it was a little Christian private school, the kids are scoring really high, they are really doing amazing things, and yet this Administration and this Congress is cutting off the tuition and grants to them. These are all inner city kids who are poor.

I talked to a single parent who said this was their opportunity, this was their way out, and yet so I feel the inconsistencies of saying we are doing this or putting all this in, but yet we just throw these inner city kids in.

Dr. BEMENT. I won't argue that. One of the very best schools in this whole area is in the District, it is at Howard University, it is their middle school, their university school, and they take children I guess from about 7th grade, it is a middle grade, 6th grade. And so it is six to eight, and since they have an open enrollment policy, it is required in the District that they have open enrollment, they take kids into the school that don't come anywhere near the mean or the average performance of the other kids. Within about a semester they brought them all up to speed.

By the time they are finished in the middle school the big challenge is what do they do next? I mean they brought them to such a high level then where do they go, where do they transfer to finish out their high school? But you know, that would be a place to do a CODEL or a STAFDEL to go and visit that school and see what they do. I think you would be very much impressed.

We have another example in Alaska believe it or not at the University of Alaska in Anchorage where the issue is how do you get to the rural communities in Alaska and teach mathematics so that native Alaskans in Barrow or other places, in really remote areas, can meet the entrance requirements for university?

Well what has happened is that the graduate students at—and these are native Alaskan graduate students—decided that they would do an online distance learning program where they would connect directly with these communities and they would bring in the students and they would teach them online. And they developed innovations because they wanted to teach better than they were taught. And so they have done some remarkable things, and they have overcome that deficit. And this is self-initiated by graduate students. That would be another great STAFDEL. If you ever wanted to go to Alaska that would be a great school to look at.

So those things can happen. If it works in Alaska it should be able to work in any EPSCoR state, should be able to work in Hawaii, and should be able to work almost anywhere where you have to deal with rural school issues. And that is a best practice. That is a best practice that ought to be emulated and replicated.

Mr. WOLF. Well hopefully when you look at the kids in the inner city in some of the schools, and in my area we have great schools. Thomas Jefferson is frankly according to the U.S. News and World Report the best school in the country, and I think we have to replicate that in the inner city.

I think we agree you are doing a good job, I worry at times though when someone tells me that they are opposed to helping kids in the inner city with the tuition help because they want to improve their overall schools, but if you are a parent you can't wait. Because if you lose somebody you never get them back in a way. And so to say that their children should just wait unless we want to happen happens——

Dr. BEMENT. No, you can't wait.

Mr. WOLF [continuing]. In the interim. And I just think when you come into my—you know where I am from in Philadelphia the schools are dysfunctional in parts of it, Chicago, other parts, and I just think that is something—just how do we kind of broaden this whereby there are the opportunities for everyone.

Anyway, I will just submit the rest of the question for the record, and again wish you the best.

Dr. BEMENT. Thank you.

Mr. MOLLOHAN. Well as I indicated there is a tremendous amount of interest in this——

Dr. BEMENT. Obviously.

Mr. MOLLOHAN [continuing]. And I was premature in thinking we were closing up, but some really good questions happened after I said all those good things about you.

So let me just—let us refer to the record to see what I said and by reference will be the end of the hearing.

Thank you, Dr. Bement.

Chairman Alan Mollohan
Questions for the Record

American Recovery and Reinvestment Act

1. **Has the $3 billion provided to NSF money been allocated?**

   Answer: All funds were allocated in FY 2009, as presented in the FY 2010 NSF Budget Request to Congress.

2. **To date, how much of this funding has been spent, and what does NSF project as the timing of further commitment and outlays of this appropriation?**

   Answer: As of March 31, 2010, $2.68 billion has been obligated, $225.58 million has been expended, and 4,889 grants, contracts, cooperative agreements, and fellowship actions have been processed against NSF's ARRA appropriation for the Research and Related Activities, Education and Human Resources, and Major Research Equipment and Facilities Construction accounts.

   NSF obligated 89 percent of its ARRA funding by March 31, 2009 and anticipates that all ARRA funds will be obligated by September 30, 2010. The principal areas yet to be obligated are:

   - All Major Research Instrumentation (MRI) except one requiring an environmental impact assessment, and Science Masters Program awards, expected to be made in June, 2010. The final MRI award will be made by September 2010.
   - EPSCoR awards, expected to be completed by June, 2010.
   - Academic Research Investment (ARI) awards, expected to be completed by September, 2010.

3. **What difference is this support making in the research community?**

   Answer: From FY 2005 to FY 2008 the number of competitive proposals received averaged around 43,000 per year and the funding rate hovered around 25 percent. In FY 2009, NSF received just over 45,200 proposals. Additional support through ARRA enabled NSF to increase its funding rate to 32 percent in FY 2009, the highest since FY 2000. Note that ARRA funds were made available for obligation seven months into FY 2009. At that time, many programs had already declined proposals ranked as "very good" to "excellent." With the receipt of ARRA funds, NSF was able to reconsider some of these. Of this group, three hundred and eighteen proposals of the 4,599 awarded with ARRA funds, or 7 percent, were able to be supported.

The funding rate for new (young) principal investigators was 23 percent in FY 2008, before ARRA, and 29 percent in FY 2009, including ARRA. Without ARRA, NSF estimates that the new investigator funding rate would have dropped to around 19 percent in FY 2009.

4. How many jobs and how many research fellowships have been supported with the stimulus funds?

Answer: Jobs reporting lags behind the start of ARRA awards by three to six months. Since most of the awards were finalized late in FY 2009, the jobs impact is only now being identified. Recipient reporting for the quarter ending December 31, 2009 suggests almost 2,900 jobs as a result of ARRA funding, which tracks with NSF's estimates of over 40,000 people (researchers, students, K-12 teachers, other professionals) eventually being involved with ARRA in some fashion. Recipient reporting for the quarter ending March 31, 2010 are just now being received and analyzed. The next few quarters will give us a much fuller picture of the jobs impact.

NSF has made 160 fellowship awards as of March 31, 2010. This number includes both direct funding of individuals as well as block grants to institutions to award to their students. A total of 387 individual Graduate Research Fellows were awarded using ARRA funds.

STEM Education

5. How can NSF solicitations in Research and Related Activities be modified to encourage inclusion of inquiry in STEM college courses?

Answer: The NSF already includes the following language in all solicitations, which explicitly encourages engaging students in the process of scientific inquiry:

"Integration of Research and Education. One of the principal strategies in support of NSF's goals is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions provide abundant opportunities where individuals may concurrently assume responsibilities as researchers, educators, and students and where all can engage in joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives. (Note: emphasis.)

6. **How can the TUES/CCLI program in Education and Human Resources encourage science and engineering faculty in to encourage inclusion of inquiry in their college courses?**

   Answer: The newly released TUES solicitation, focuses attention repeatedly on aligning instructional practice with what is known from research about how people learn. This research includes substantial documentation of the importance of inquiry-based teaching, and we expect to see this element as a central focus of TUES proposals. Another focus of the solicitation is the funding of activities that will bring about widespread implementation of instructional practices that engage students deeply; again many such proposals would focus on inquiry-based instruction.

7. **How do the TUES/CCLI, REESE, and NSDL programs disseminate inquiry-based instructional materials and approaches at the undergraduate level?**

   Answer: The REESE, TUES/CCLI, and NSDL Programs all disseminate inquiry-based instructional materials. For specifics, see below.

   Inquiry-based instructional materials and approaches at the undergraduate level developed with funding through the REESE program are disseminated through principal investigator (PI) meetings, professional meetings, and peer- reviewed publications. In addition, the REESE program has a resource network that maintains a publically available website (https://arc.uchicago.edu/reese/) that contains a structured abstract of each project along with findings and publications.

   TUES/CCLI and NSDL PIs also disseminate inquiry-based instructional materials through PI meetings, professional conferences, and articles in peer-reviewed journals. NSDL also has a website (http://nsdl.org) that is a free online library of resources for STEM education and research. Since its "Invention and Impact" conference in 2004 the TUES/CCLI program has sponsored periodic PI meetings that bring together several hundred leaders in undergraduate STEM education to share their learning resources and best practices. A second meeting was held in summer 2008 and plans are underway for a next meeting in early 2011. Since its inception the NSDL program has held an annual meeting that initially brought together PIs, but has increasingly seen attendance by members of the larger educational enterprise.

   Further, the TUES/CCLI program explicitly calls for projects that bring about widespread implementation of instructional practices that have been shown to improve student learning, including inquiry-based instruction. Such projects typically conduct workshops of long enough duration for participants to learn the new approach and work together on strategies for adapting it to their home context. They also typically support follow up activities that encourage persistence in the new practice.

8. **How do the GK-12 and CAREER programs specifically prepare the faculty of tomorrow to include inquiry in their teaching and how can this be strengthened?**

Answer: The solicitations for the GK-12 and CAREER programs call for preparing tomorrow's faculty to both teach and integrate research and education.

For example, awardees in the GK-12 program are expected to provide pedagogical experiences for their graduate students, and many of these incorporate inquiry-based learning. The GK-12 solicitation specifies that PIs "Describe how they will enhance K-12 STEM knowledge and instruction in the specified schools and school district, including as appropriate, their role in implementing inquiry-based instructional strategies and materials." An evaluation in progress by Abt Associates indicates that 78 percent of current GK-12 fellows and 76 percent of former fellows reported that they planned, coordinated, and/or facilitated inquiry-based learning activities for K-12 students.

Each CAREER project requires a specific emphasis on the integration of education and research. The CAREER program emphasizes the importance the Foundation places on the early development of academic careers, and is dedicated to stimulating the discovery process in which the excitement of research is enhanced by inspired teaching and enthusiastic learning. The educational activities may be in a broad range of areas and may be focused on students at any level, or on the informal learning arena. For instance, the CAREER program solicitation calls for preparation of faculty for inquiry-based instruction. A draft evaluation report [Carney, Jennifer et al., Evaluation of the Faculty Early Career Development Program (CAREER), Cambridge Ma: Abt Associates, 2008] found "CAREER awardees are more likely to engage with K-12 students or teachers. CAREER awardees are significantly more likely to work with students or teachers at the K-12 level, suggesting that receipt of the CAREER award may increase outreach to K-12 schools." To further strengthen this program, NSF will continue to work with potential awardees at various outreach and proposal writing workshops that focus greater emphasis on the effective integration of research and education.

9. **Should use of inquiry-based science instruction be required of all institutions of higher education receiving federal research funding?**

   Answer: In response to NSF's Broader Impacts criterion, researchers who apply for NSF funds collectively propose a variety of activities that are appropriate to their research goals and their institutional context. Many proposals seek to improve undergraduate curriculum and laboratory experiences in response to this criterion. A specific requirement of this type might actually limit the range of creative efforts with broader impacts that NSF PIs propose.

10. **Witnesses stated that one obstacle to effective implementation of inquiry is the added resources required for formative and evaluative performance assessments; should NSF undertake a grant program to fund inquiry evaluators to work with teachers and schools to provide these capabilities?**

    Answer: The NSF Discovery Research K-12 program (DRK-12) (current solicitation: NSF 09-602) focuses on improving assessment of student STEM knowledge and skills. In particular, this program develops and studies formative and high-stakes summative assessments of STEM learning that indicate achievement of the most important disciplinary content, concepts, principles, skills, and reasoning, along with the application of that knowledge to problem-solving and decision-making.

    As illustrated below, the current solicitation and its predecessors in the DRK-12 program have elicited a number of strong proposals for projects to develop and test efficacy of assessments aimed at measuring student inquiry skills. Some examples of projects focused on inquiry skills are listed below

Award ID	Brief Description
0733286	This project focuses on improvement of inquiry science assessment by developing a technology-based system for middle school standards-aligned assessment of inquiry skills. (PI: Janice Gobert)
0733345	This project is developing and studying simulation-based, curriculum-embedded, formative assessments of inquiry skills and complex science learning. (PI: Edys Quellmalz)
0822308	This project is creating instruments that assess student inquiry skills and content knowledge authentically through a series of virtual environment situated assessment modules. (PI: Diane Ketelhut)

Thus the DR K-12 program currently solicits and receives proposals for work on formative and summative assessment of STEM learning, with a substantial focus on inquiry-based learning. Further efforts to help school systems and teachers implement assessment tools are undertaken by the NSF Math and Science Partnership program.

11. Are education department faculty prohibited from serving as principal investigators in the GK-12 program, and if so, why and is this appropriate given the roll education departments play in educating and recertifying K-12 teachers?

Answer: The GK-12 solicitation, NSF 09-549, in the PI Limit section, does state that "The lead Principal Investigator (PI) must be a STEM discipline faculty member actively conducting STEM research at the lead institution...Faculty members whose primary research is on science education (e.g. physics education, technology education, mathematics education, engineering education, etc,) are not eligible to serve as the lead PI." Faculty in STEM education may serve as Co-PIs. EHR is currently reviewing the impact of this restriction for PIs for consideration in future GK-12 solicitations.

This restriction arose historically from the intention of the program to draw in STEM disciplinary faculty by insisting on their engagement. The program is structured to bring current STEM disciplinary research into the K-12 classroom, so as to provide hands-on experience for teachers and children that is directly connected to the research of the STEM faculty. A further significant purpose of the program is to catalyze a stronger awareness on the part of both graduate students and STEM disciplinary faculty of the challenges facing K-12 teachers, and also to facilitate the two-way learning about effective instruction that occurs when STEM disciplinary faculty and students interact with the excellent K-12 teachers they encounter in this program.

12. To what extent are science and engineering graduate students funded under the GK-12 receiving training in inquiry-based instruction before or during their work in K-12 classrooms, and to what extent is this required or favored in selection criteria during proposal review?

Answer: Each project determines and proposes the type of training that fellows will receive. Training includes methods of instruction along with training in communication and team-building skills. Formal training for fellows occurs either before or during the GK-12 fellowship experience. It should be noted that many fellows have had prior K-12 experiences before entering graduate school at GK-12 institutions.

As stated in the current solicitation for the program, one of the specific review criteria for the program is to place emphasis on "mechanisms for incorporating fellows' research into K-12 settings". The program solicitation clearly asks that the project plan "describe how they [fellows] will enhance K-12 STEM knowledge and instruction in the specified schools and school district, including as appropriate their role in implementing inquiry-based instructional strategies and materials".

13. To what extent did NSF systemic education initiatives encourage the use of inquiry in K-12 schools, and what were the results?

Answer: The NSF sponsored three principal initiatives for addressing systemic reform activities during the period from 1991 through 2003. Below are findings from research and evaluation of the NSF systemic initiative portfolio. Also included are examples from the solicitations for the three systemic initiatives.

Statewide Systemic Initiative (SSI):
One-half (13 of 26) of the state initiatives had strong positive impacts on classroom practice, as measured by change in instruction toward inquiry-based learning and alignment with state and national standards [Council of Chief State School Officers. (2000). *Summary of findings from SSI and recommendations for NSF's role with states: How NSF can encourage state leadership in improvement of science and mathematics education.* (Report No. ISBN: 1-884037-65-8) Washington, DC].

There were "strong, positive impacts on classroom practice, meaning that there was reasonable evidence of changes in curriculum and instruction toward more inquiry-based learning." [Zucker, A. A., Shields, P. M., Adelman, N. E., Corcoran, T. B., & Goertz, M. E. (1998), *A report on the evaluation of the National Science Foundation's statewide systemic initiatives Program.* Menlo Park, CA: SRI.]

The solicitation (NSF 90-47) language specified the following as inquiry-oriented aspects of the SSI projects "...Scientific and mathematical ways of thinking and solving problems; the use of probability and statistics; practice in experimenting, gathering evidence, making and testing hypotheses, and constructing theories; working alone and in groups; . . making conjectures, and proving relationships; . . . use of evidence and logic in making arguments and solving scientific, mathematical and technological problems. ..".

Rural Systemic Initiatives (RSI):
Evaluators found that "rural educators are committed to introducing teachers to hands-on science and familiarizing them with an inquiry approach to teaching [and learning]. A significant number of communities are making progress toward a philosophical shift to hands-on and inquiry-based instruction. Several RSIs, particularly Native American Communities, integrate culture and language into their science curriculum" [Education Development Center. (2002). *Science education reform in rural America: A snapshot.* Newton, MA].

Another review found that "... the Alaska RSI, developed an original science curriculum in 1999, Village Science, that enables teachers to teach science to students using examples from village life. . . , while [t]eachers on the Flathead Reservation (Montana) worked with RSI staff at Salish Kootenai College to write culturally competent, inquiry-based curriculum units based on constructivist learning theory,"[Systemic Research, Inc. (2005). *Bringing science and* *mathematics excellence to rural classrooms: RSI program highlights and case stories of seven sites*. Norwood, MA].

The solicitation (NSF 97-33) language specified "...An overarching goal of the RSI is the improvement of science, mathematics and technology education in rural, economically disadvantaged regions of the nation, including, but not limited to, access to high-quality, standards-based instruction, innovative use of educational technologies for interactive delivery of instruction, and the training of the teaching workforce to meet the demands of a new instructional paradigm."

Urban Systemic Initiatives/Program (USI):
In a 2001 evaluative study of 22 USI sites, nearly all were found to have decreased their emphasis on lecture and demonstration methods of teaching and moved towards inquiry-based instruction. [These findings presented] evidence of noteworthy gains in student achievement, with the greatest gains seen in school districts that have participated in the USI program for the longest period of time. [These districts have] substantially increased their enrollment rates in mathematics and science gate-keeping and higher-level courses. Underrepresented students made even greater enrollment gains than their peers during the same period, resulting in reduced enrollment disparities [Systemic Research, Inc., (2001), *Academic Excellence for all Urban Students*, Norwood, MA].

The solicitation (NSF-99-52, USP) language specified "...The main goal of the Urban Systemic Initiatives/Program is to improve the urban school district's implementation of a standards-based, inquiry-centered science, mathematics, and technology education for all students K-12."

14. Is NSF recommending systemic approaches and the inclusion of inquiry in STEM education to the Department of Education, and if so, what are the plans for achieving implementation of inquiry-based STEM education across the country?

Answer: Staff at all levels from the NSF (including the deputy director, EHR assistant director, division directors from EHR and CISE, and program officers) and the U.S. Department of Education (including special assistant for STEM education, representatives of the Institute of Education Sciences director, National Center for Education Statistics staff, and program officers) have been meeting and conferring regularly and are in the process of developing a multi-pronged approach for scaling-up projects that have been funded by NSF and that show promise of impact based on preliminary evidence. Projects include K-12 instructional materials and teacher education models. Most of the materials and projects that NSF supports (particularly in science education) are based on the importance of giving students opportunities to interact with real-world phenomena, to use tools to gather, analyze, and interpret data; propose answers, explanations and predictions; and to communicate results. NSF is also drawing on its history of experience with the systemic initiatives to underscore the importance of a multi-pronged approach to reform.

15. **What steps has NSF recommended to the Department of Education to improve the understanding of STEM education and its support by states, school superintendents, and principals who often lack any understanding of STEM education or experience in inquiry-based instruction?**

Answer: As noted above, staffs from NSF and U.S. Department of Education have been meeting regularly to develop a common agenda for improving STEM teaching and learning. As part of that larger agenda, NSF is planning a workshop with chief state school officers to begin identifying the barriers and opportunities that states face in implementing STEM education reform, to occur sometime in the next six months.

16. **What efforts is NSF undertaking to work with states to strengthen STEM education in K-12 classrooms and what are the successes and challenges to date?**

Answer: NSF's direct funding typically supports the educational research and development activities of local education teams – varying mixes of schools, school districts, informal science education entities, and institutions of higher education – in support of states' concerns with educational standards, curriculum, assessments, teacher preparation, and teacher professional development. A considerable effort of the past decade to inform statewide action in STEM education is through NSF's Math and Science Partnership (MSP) program, which coordinates its efforts with the MSP program of the U.S. Department of Education (ED). A major part of this coordination is disseminating new knowledge gleaned from the NSF projects – largely partnerships of school districts and institutions of higher education – to the ED state coordinators (who most often reside in state education agencies) and to the ED-funded MSP project participants for designing, implementing and evaluating their programs. This is accomplished at regional and national meetings, and through access to www.mspnet.org, NSF's electronic community for projects in its portfolio as well as a major dissemination vehicle to the STEM education community.

In some NSF MSP projects, state agencies are key participants in the work. For example, the project called PRISM (Partnership for Reform in Science and Mathematics) involves the Georgia Department of Education as well as the University System of Georgia and the Georgia Board of Regents. Other state entities have been active in MSP projects in Maryland, North Carolina, and Rhode Island. Lastly, a number of NSF MSP principal investigators whose project work is local are also very involved in disseminating their efforts in statewide channels.

A challenge to NSF's funded activities informing the work of states resides in the typically limited capacity of state educational entities to utilize new insights of the educational research literature in light of state policy directions that often are not informed by such literature. In addition, the educational work of states is often driven by local education agencies that have their own cultures and policy directives.

17. What has been the effect of the National Academy of Sciences recommended national science education standards released in 1996, and would an update of them be helpful to NSF in its work with states?

Answer: The National Science Education Standards (NSES) have provided, for many states, guidance in the development of state-level standards. According to a 2003 report from the National Research Council (NRC), "*What is the Influence of the National Science Education Standards?*," the NSES have influenced states in the areas of curriculum, professional development, and teaching and teaching practice, although the uptake has been somewhat uneven across the states. Given that these standards were developed in the early 1990s, updates being developed 20 years later can incorporate the much stronger empirical evidence that now exists on how people learn. The NRC report acknowledged that it is impossible to teach everything in the NSES. There is growing consensus that future standards must address a narrower set of "core" ideas in science. This is echoed through many international comparisons with high achieving countries that have a more focused and coherent approach to science teaching. If a narrower focus can be maintained through a new set of standards, then this update would be helpful to NSF in its work with states, as well as in more focused research on science teaching and learning.

18. In NSF's experience, to what extent do state education authorities work with the STEM communities in their states in designing, implementing, and evaluating their STEM education programs?

Answer: The degree to which state education authorities work with STEM communities to design, implement and evaluate their STEM programs depends on multiple factors, including past histories of collaboration and the degree to which the state has engaged in prior efforts to improve STEM education, often through NSF grants. Several of the states that previously worked with NSF's Statewide Systemic Initiatives program (SSI), for example, connected state agencies, higher education institutions, professional organizations and members of the business community. In some cases these partnerships have persisted beyond the life of the SSIs. Some of those partnerships competed successfully for NSF's Math and Science Partnership awards. For instance, the early MSP comprehensive, multi-year projects expanded the partnerships that enabled cooperation between state and local education authorities and important STEM communities. MSP is a partnership program between higher education and local school districts, and while some of those projects actively work at the state level (e.g., Georgia's PRISM project, Vermont) most are conducting local work.

19. How is NSF working with other science and engineering agencies – NOAA, NASA, NIST, USGS, USDA Ag Research Service, etc. – to bring the STEM perspective to the Department of Education programs in STEM education?

Answer: NSF has ongoing relationships, and will continue to develop collaborations, to integrate its STEM education perspectives with other science and engineering agencies, and share these perspectives with the Department of Education. Following are specific examples of current activities:

- The National Research Council's NSF-funded Climate Change Education Roundtable will soon commence activities, including representation from several science agencies (NOAA, NASA, and NSF) and the Department of Education.
- NSF, NOAA and the Department of Education are working together through the U.S. Global Change Research Program Education Interagency Working Group (USGCRP EdIWG).
- NSF is working with the Department of Energy on RE-ENERGYSE. The two main elements of RE-ENERGYSE include 1) the establishment of a Collaboration for Research and Education (including grades K-12) on Energy and a Sustainable Environment and 2) the development of a proactive education and awareness campaign on renewable energy.
- ScienceEducation.gov – managed by the Interagency Science Portal Education Coordinating Group (ISPECG) – is a collaboration among several agencies including Education. Although NSF has not signed on to the protocol, (nor has the Department of Education) we both have participated in all meetings. NSF will be hosting a meeting with DOE and Education on the Science Education portal.
- The Taskforce on Aerospace Workforce Revitalization has representatives from NASA, DoE, DOD, and NSF as members. Together we work to create programs, outreach activities and events to stimulate interest in STEM careers in general.
- The NSTC Education Subcommittee, jointly co-chaired by representatives from NSF, U.S. Department of Education, and NIH, involves representatives from all science agencies concerned with education. Currently the subcommittee is undertaking a project to describe best practices and their impacts in teacher professional development in science laboratories.

20. What interaction and coordination is happening between NSF and the Institute of Educational Sciences and what effect will their research funding have on NSF funding of educational research?

Answer: There is close interaction and coordination between IES and the NSF. The NSF Director serves as an ex officio member of the National Board for Education Sciences, which oversees IES, and thus has been involved in discussion of IES direction for several years. Dr. John Easton, IES Director, spoke about possible IES and NSF interactions during his presentation at the February 3, 2010 meeting of the National Science Board. He and Dr. Joan Ferrini-Mundy, Acting Assistant Director, NSF Directorate for Education and Human Resources, regularly communicate about a variety of topics, including: standards of what constitutes rigorous evidence for educational research and development activities; evaluation of STEM teacher professional development; and the complementarity of the IES and NSF STEM education research programs. The IES offers a Mathematics and Science Education funding opportunity as part of its Education Research Grant Programs, (http://ies.ed.gov/funding/ncer_rfas/mathsci.asp), and has funded a number of effectiveness studies to assess impact of instructional materials and resources, many that were designed originally with support from NSF's research and development programs. NSF's educational research investments have traditionally emphasized basic research about STEM learning and teaching, development of assessment tools, learning in informal environments, and design research to develop instructional learning materials. NSF's educational research investments span all age levels, and both in-school and out-of school environments. IES programs support research about efficacy and scale-up of such tools, particularly at the K-12 level. There is considerable overlap in the principal investigator (PI) base for both organizations, and good opportunities for systematic complementarity.

Community Colleges

21. Given the President's statements regarding the need to achieve universal education above the high school level and the large proportion of college students being educated by community colleges, what should NSF be doing to strengthen STEM education generally at community colleges?

Answer: Through the Advanced Technological Education (ATE) program NSF is learning about the current and coming needs and opportunities for the community college system (with now more than 1,000 community/two-year colleges nationwide) as part of the system that prepares the STEM workforce. Arising from work in ATE, NSF has a robust partnership with the American Association for Community Colleges. We expect to continue that close interaction, so NSF programs address the particular concerns of community colleges.

Not only do community and two-year institutions prepare technicians in a range of emerging and critical areas in the STEM workforce, they also provide the foundational preparation for more than 40% of holders of bachelors and masters degrees in science and engineering (see Tsapogas, 2004, http://www.nsf.gov/statistics/infbrief/nsf04315/). And community colleges provide the basic mathematics and science training currently for a large proportion of the Nation's teachers. Thus NSF is highly committed to strengthening education in these institutions.

A number of NSF programs in addition to ATE welcome applications for innovative research and development activities from community colleges, as well as partnerships that include community colleges, and have community colleges as part of their portfolios (e.g., TUES/CCLI, MSP.) Some programs provide larger awards to 4-year colleges and universities when they partner with community colleges, and we plan to expand the range of programs that encourage such partnerships.

22. What role should community colleges be playing in the reform of STEM education and the broad inclusion of inquiry therein?

Answer: Community colleges bring a number of key assets to the overall reform of STEM education, including the ability to mount new programs for workforce development in technical areas quickly, and using innovative approaches to experiential learning. Faculty generally focuses on quality instruction and thus can provide important direction for innovation in undergraduate STEM teaching, including inquiry-based and problem-based approaches to instruction. In the area of mathematics particularly, community colleges lead the higher education community in developing effective approaches to developmental mathematics and to solving problems of readiness for college mathematics.

23. To what extent do the grants funded through the ATE program achieve more in STEM education than just their primary purpose of preparing technicians for the workforce?

Answer: In ATE centers and projects, two-year colleges have a leadership role and work in partnership with universities, secondary schools, business and industry, and government agencies to design and carry out model workforce development initiatives. As noted before, community colleges have a dual mission of direct workforce preparation and provision of the foundational years for students who continue elsewhere to four year degrees and beyond. This dual mission is mirrored in ATE projects. While the curricula funded are developed in partnership with specific industries, they emphasize STEM education that prepares students for development and change as their careers progress.

The ATE program also has had a significant impact on teacher education for both pre-service and in-service teachers and faculty. The teacher preparation track of the ATE program has provided enhanced STEM education for prospective teachers (*The State of Affairs: Impact and Implications of STEM Teacher Education at Two-year Colleges*, 2009, p 29-32) as well as impacting the institutions involved (*The State of Affairs: Impact and Implications of STEM Teacher Education at Two-year Colleges*, 2009, p. 33-34). In addition, faculty professional development is an integral part of a majority of ATE projects involving new and emerging technologies.

Minority Serving Institutions

24. What was the reasoning behind NSF's proposal of a combined undergraduate education program for all minority serving institutions – historically black colleges and universities, Hispanic serving institutions, and tribal colleges?

Answer: While an increasing number of students plan to major in STEM fields, the completion rates for underrepresented minorities continue to lag far behind those of their majority counterparts. As the U.S. seeks to strengthen its STEM enterprise as outlined in the America COMPETES Act, the effort demands new resources and tactics for professional STEM workforce development, especially among populations historically underrepresented in STEM fields. Three current NSF programs – the Louis Stokes Alliances for Minority Participation (LSAMP), the Historically Black Colleges and Universities Undergraduate program (HBCU-UP) and Tribal Colleges and Universities Program (TCUP) -- have established records of facilitating learning and research by tens of thousands of underrepresented minority undergraduate students pursuing STEM careers.

NSF seeks to implement a new program to catalyze next-generation capacity to produce a diverse STEM workforce with 21st century knowledge and skills -- one that is able to contribute to the Administration's vision for new opportunities in the energy, environment, and technology sectors, and to the scientific enterprise more generally. This new program has the working title "Comprehensive Broadening Participation of Undergraduates in STEM" (CBP-US), and we plan to continue to honor the commitment of Congressman Louis Stokes in the program terminology as planning proceeds. CBP-US will be introduced in FY 2011, but existing programs will not be terminated abruptly. NSF intends to develop a five-year transition period of bridging between programs. During the planning and transition, we expect to incorporate community feedback in shaping the new program.

The goal of CBP-US is to enrich the quality and innovation potential of tomorrow's STEM workforce through comprehensive broadening participation of undergraduates in STEM. The program will catalyze creation of exciting opportunities that attract and retain STEM undergraduates at historically black colleges and universities, tribal colleges and universities, Hispanic-serving institutions, and other minority-serving institutions. In addition, majority-serving institutions of higher education with strong track records and great potential in producing underrepresented STEM graduates will be eligible. It will also build capacity by drawing on research and best practices across the range of institution types represented in EHR programs. Investments in this area can lead to strong alliances and high-quality institutional efforts to broaden participation and provide highly qualified participants for the STEM workforce. The proposed program will blend proven strategies from established work, adapt and improve those strategies in different contexts from which they originated, and leverage intellectual and fiscal resources to develop new ways to broaden participation in both STEM undergraduate education and, by extension, the science and engineering workforce. It is also essential to heighten efforts to build knowledge about the innovative and effective ways of doing so.

25. What was the rationale for the requested increase of $13 million above the combined level of the antecedent programs, and how does this take into account the likely needs and grant pressure from Hispanic serving institutions?

Answer: The FY 2011 budget request increase of $13 million brings the total FY 2011 budget request for CBP-US to $103 million. The additional requested dollars enable the agency to begin expansion to reach previously underserved communities and create new research and development opportunities in broadening participation that are forward-looking and draw on the accumulated knowledge of our existing programs.

The new efforts will be strengthened by resources leveraged throughout NSF. A central effort in developing the new comprehensive program will be establishing strong linkages to other NSF programs in both the Education and Human Resources Directorate, and in the disciplinary research directorates in order to leverage more resources for the overall commitment to broadening participation at the Foundation. In addition, developing and expanding promising linkages with other agencies and foundations will be major efforts in developing the new program.

26. What will be the components of this combined program – what will be the different solicitations?

Answer: The combined program would feature strands within a single solicitation that reflect the successes and best practices of the current undergraduate programs. Our current conceptualization of these strands is as follows, and over the coming months we will be inviting conversation and discussion with the field to shape the program:

- Louis Stokes Model Alliances: Alliance projects will develop intramural networks and collaborations among institutions for information sharing, program assessment, development of instructional materials and curricula, and opportunities for cross-institution participation in STEM research by undergraduates.

- Transformational Initiatives: These projects will build capacity and infrastructure at MSIs to integrate education with research and other forms of activity-based learning within and across these institutions.
- Targeted Initiatives: These projects will focus on the contextual needs, growth and development, and the continuous improvement of STEM education at the MSIs.
- Educational Research: Research into overcoming barriers and solving the "grand challenges" of broadening participation will thread through all program components. Relative to broadening participation, the objective will be to move STEM education and research to the next level of innovation and impact.

27. How will grants in this or any other NSF program help young investigators at minority serving institutions compensate for the general lack of institutional resources and reputation generally required to succeed in the normal peer review process in their pursuit of research grants?

Answer: The HBCU-UP, LSAMP, and TCUP programs emphasize the building of capacity for teaching and learning (stressing inquiry-centered learning and the integration of research and education), and research opportunities, that enable the establishment of a strong base of young faculty ready to engage in promising research and education at their institutions. This extant emphasis on building intellectual infrastructure will be reinforced in the new, combined CBP-US program. Further, NSF seeks out faculty from minority-serving institutions (as well as all institutions of higher education) to serve on grant review panels in order to provide them the opportunity to meet leaders in their disciplinary fields, stay current on emerging areas of research, and immerse themselves in the process of proposal review. The NSF CAREER program also invites proposals from young faculty who are within tenure track positions and embrace the integration of research with education.

Research Vessels

28. With the melting of Arctic Ocean sea ice, missions beyond research in high northern latitudes are likely; how will this affect NSF's polar research program and ice breaker support for this research?

Answer: The U.S. Coast Guard (USCG) has stated that melting sea ice in the Arctic will increase its need to support missions other than scientific research at high latitudes. The USCG has also stated that the *Healy*'s primary mission is to meet U.S. needs for a research platform in the Arctic. In fact, the science community has benefited from nearly exclusive use of the *Healy* since its commissioning a decade ago. Even so, the science community would use more time on the *Healy* if it were available. An increase in other-than-science missions will reduce the number of days available for scientific research, a resource already limited to approximately 185 days by the single crew assigned to the vessel.

Future decisions by U.S. policy makers will require research that improves our ability to predict future changes in the Arctic Ocean, its ecosystems and its coastal communities on a region by region basis and on varying time scales. The changes in the Arctic will inevitably impact environments and economies far south of the Arctic and may already be doing so. While summer sea ice is expected to decrease in the area, winter sea ice and ice in the deep Arctic Ocean will hinder access for research purposes for decades to come. With decreasing availability of USCG icebreakers the research program will be further limited. The scientific community will benefit from the availability of the Alaska Region Research Vessel, the R/V *Sikuliaq*, when she comes on line in a few years, but this vessel could not operate in the same area as a *Healy*-type vessel. NSF is initiating a study to explore options for meeting this need in the most cost-effective and efficient manner. In the meantime, NSF and USCG together convene an annual interagency scheduling meeting to consider all national and maintenance requirements for the icebreakers, and schedule accordingly as resources allow. To date this has been an effective mechanism, but the need for icebreaking may grow faster than current capabilities.

29. What is the current status of the US research vessel fleet, including blue water, coastal, and ice breaker class ships?

Answer: There are presently 21 ships (a reduction of two ships in the last two years due to retirement and transfer) in the US Academic Research Fleet, including six Global Class, five Ocean/Intermediate Class, seven Regional Class and three Local Class. These ships are owned and operated by a combination of federal and state agencies, and private oceanographic institutions. The University National Oceanographic Laboratory System (UNOLS) consortium structure is used as the coordination mechanism for efficient ship scheduling, sharing of best management and operational practices, and providing the federal agencies with oceanographic community inputs on Fleet improvements and renewals. In addition there is one NOAA owned and operated Global Class ship and three United States Coast Guard Icebreaker Class vessels.

30. What is the comprehensive plan for the US research fleet and has such a plan been developed in consultation with NOAA, Coast Guard, Navy and potential international partners?

Answer: The federal agencies discuss their individual ship program plans through regular meetings of the Interagency Working Group on Facilities. The US Academic Research Fleet Status Report published in 2007 described the current research Fleet and outlined the near-term plans for ship renewals. The Office of Naval Research (ONR) and NSF commissioned a National Research Council (NRC) study, entitled "Science at Sea: Meeting Future Oceanographic Goals with a Robust Academic Fleet" whose recommendations were briefed to the agencies in late 2009.

A number of fleet renewal activities are underway, consistent with earlier reports. ARRA funding is supporting the construction of the new Alaska Region Research Vessel R/V *Sikuliaq* by Marinette Marine Corporation through an award to the University of Alaska Fairbanks by the National Science Foundation. This ship is expected to enter service in 2014. The US Navy is proceeding with the acquisition of two new Ocean Class Research Vessels which are planned to replace the Global Class R/V *Knorr* and R/V *Melville* in 2014. Awards to two design teams have been completed with a down-select to a single design planned for early 2011 to support construction start for the lead ship in mid-2011. The National Science Foundation completed a design down-select in early 2010 for the Regional Class Research Vessel renewal efforts with plans for possible construction start in 2012. The International Ship Operators Meeting (ISOM), which is hosted by a different nation each year, is the forum used to share ship program information and plans with international counterparts.

EPSCoR

31. What was the basis of the level for EPSCoR in the FY11 budget request?

Answer: The FY 2011 Request level of $154.36 million for EPSCoR is consistent with the three-year growth trend for the R&RA account for FY 2009 through FY 2011. The allocation of the request across EPSCoR program activities reflects the relative reach and impact of these investment strategies that are designed to catalyze sustainable growth in research competitiveness across EPSCoR jurisdictions. The FY 2011 decrease in RII and increase in Co-funding activities relative to the FY 2010 funding levels reflect a rebalancing of the EPSCoR portfolio following full implementation of RII Track-2 and the ARRA-supported RII Intercampus and Intracampus Cyber Connectivity (C2) programs in FY 2009 and FY 2010.

32. How, when and why has the EPSCoR program grown in the number of states included?

Answer: The number of jurisdictions participating in NSF EPSCoR activities has grown as the eligibility criteria have evolved over the 32 year tenure of the program.

At the outset of the NSF EPSCoR program in 1978, eligibility was determined through a multistep analysis of a state's success in competing for federal scientific research project support, starting with a 'funding gate' that limited eligibility to states receiving less than one million dollars per year in two of the last three fiscal years. Seven states (Arkansas, Maine, Montana, North Dakota, South Carolina, South Dakota, and West Virginia) met the full set of eligibility criteria. In FY 1980 the seven states competed for five EPSCoR awards, each worth up to three million dollars over a five year period. Following NSF's comprehensive merit review of the proposals, five states (Arkansas, Maine, Montana, South Carolina, and West Virginia) received awards.

A similar ranking procedure with modified eligibility criteria was employed in 1984 to select additional states for a second round of EPSCoR grant competition. For example, the "funding gate" applied as a qualifying criterion was increased from one million dollars to three million dollars of scientific research project support from the Foundation in two of the latest three fiscal years. Eleven additional states and the Commonwealth of Puerto Rico met the full set of seven eligibility criteria. Awardees in 1986 included Alabama, Kentucky, Nevada, North Dakota, Oklahoma, Vermont, Wyoming, and the Commonwealth of Puerto Rico, bringing the total number of EPSCoR awardees to thirteen.

Four states (Idaho, Louisiana, Mississippi, and South Dakota) submitted revised requests for 3 years of EPSCoR support in FY 1988, and each received an award of up to $600,000 per year. Congressional instructions also allowed the original 5 states to recomplete for additional EPSCoR support in 1989, and each received 2 year awards also worth approximately $600,000 per year, bringing the total number of EPSCoR jurisdictions at that time to seventeen.

As noted above, prior to 1991 a fixed dollar amount of NSF research obligations awarded to a state over a three year period was used as the initial filter to determine the eligibility of states for EPSCoR consideration. In 1991 this criterion was changed to a percentage (0.50% or less) of NSF research obligations to universities and colleges over the latest three year period. Five additional states met this criterion. In 1992 the number of EPSCoR eligible jurisdictions grew to 19 with the addition of Kansas and Nebraska.

During 2000-01, three additional states (Alaska, Hawaii, and New Mexico) joined the list of EPSCoR participants. EPSCoR's reputation for helping states achieve demonstrable gains in academic research competitiveness generated increased interest in the program and resulted in direct Congressional requests to the NSF Director for participation in the program. The NSF agreed to work with the states and planning grants were awarded to establish EPSCoR governing committees in each of the three states as a first step to full participation in the program. During this same period, in response to a request from the Governor General of the U.S. Virgin Islands, the Assistant Director of NSF's Education and Human Resources Directorate created an EPSCoR-like planning and assistance program for the territory.

A simplified eligibility criterion based on the level of NSF research funding was proposed and approved by the NSF Director in FY 2002. Each year, the Foundation, through the Office of Budget, Finance, and Award Management, compiles summary data for the preceding 3 years of NSF research funding by state. Eligibility to participate in the EPSCoR Research Infrastructure Improvement (RII) competition is based on these data. Eligibility was originally restricted to those states that received 0.70% or less of the total NSF research funds to all recipients within a state averaged over the preceding three year period. In FY 2003, Congressional instructions resulted in raising that percentage to 0.75%. In instances where a single large NSF funded national or international facility skews the data, an adjustment is made.

Based on the 0.75% criterion, in FY 2010, 27 states plus the Commonwealth of Puerto Rico and the U. S. Virgin Islands are eligible to compete in one or more elements of the EPSCoR program. The 0.75% criterion is one of two primary considerations, the second being that a jurisdiction must demonstrate a commitment to develop its research bases and to improve science and engineering research and education programs at its colleges and universities prior to submission of proposals to any of the EPSCoR funding programs. While success rates in the Research Infrastructure Improvement award programs are higher than many NSF programs, these are not guarantees of funding. A rigorous merit review process coupled with strong program management during the multi-year award period assures strong intellectual merit and effective broader impacts of the funded activities.

Currently eligible jurisdictions include the states of Alabama, Alaska, Arkansas, Delaware, Hawaii, Idaho, Iowa, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Vermont, West Virginia, and Wyoming, as well as the U.S. Virgin Islands and the Commonwealth of Puerto Rico.

33. What are the current criteria for inclusion of states in EPSCoR, and do the criteria for inclusion take into account the presence in a state of major government laboratories, R&D funding from across the federal government, or the population of the state – why or why not?

Answer: As noted in the above response, eligibility for participation in NSF EPSCoR activities is determined by the fraction of NSF research support funding received by a state (jurisdiction) and by that state's demonstrated commitment to develop its research bases and to improve science and engineering research and education programs at its colleges and universities.

The presence in a state of major government laboratories is not taken into account. For comparable investments, the contributions of such laboratories to the development of the research capacity, workforce development, and educational goals of a state are proportionally less than those of the state's academic institutions. Major government laboratories build national capacity in mission focused areas.

Initially, overall federal research investment in a state was considered in determining eligibility for participation in NSF EPSCoR activities. However, with the creation of EPSCoR and EPSCoR-like programs in six other federal agencies in the early 1990s, non-NSF funding was removed from the eligibility criteria.

Criteria for participation in NSF EPSCoR activities have not taken into account the population of candidate jurisdictions. EPSCoR investments are made to facilitate the development, with the state, of strategic plans that maximize the impact of the EPSCoR investment on the research capacity of the state.

34. Are there criteria for graduation from EPSCoR?

Answer: Yes. A jurisdiction "graduates" from EPSCoR when it has received more than 0.75% of NSF research support funding for a three year period.

Current Perspective on R&D

35. In what areas of R&D is NSF almost the only US source of significant funding?

Answer: The National Science Foundation is the largest provider of non-biomedical basic research funding to our Nation's universities. In FY 2007, federal agencies provided $14.164 billion for academic basic research, of which $6.386 billion was to support research in fields other than the biological and medical sciences. (Most of the biomedical basic research was funded by the National Institutes of Health. NIH provided $9.202 billion for academic basic research.) In FY 2007, NSF obligated $3.025 billion for academic basic research, more than any agency other than NIH. NSF provided all, or nearly all, of the federal support for academic basic research in chemical engineering and civil engineering, anthropology, and political science. It provided more than half of such basic research funding for mathematics and computer sciences, astronomy, environmental sciences, and materials engineering. (Please see the following table for more information.)

Federal obligations for basic research performed at universities and colleges detailed field of science and engineering: FY 2007
(Dollars in thousands)

Field	All agencies	NSF	NSF share
All fields	14,162,996	3,024,973	21.4%
Environmental sciences	795,041	455,705	57.3%
Atmospheric sciences	179,969	107,036	59.5%
Geological sciences	186,794	139,907	74.9%
Oceanography	280,447	190,808	68.0%
Environmental sciences, nec	147,831	17,954	12.1%
Life sciences	8,764,319	530,832	6.1%
Agricultural sciences	130,236	0	0.0%
Biological sciences (excluding environmental biology)	4,738,878	431,384	9.1%
Environmental biology	162,571	99,448	61.2%
Medical sciences	3,038,108	0	0.0%
Life sciences, nec	694,526	0	0.0%
Mathematics and computer sciences	862,605	653,325	75.7%
Computer sciences	563,309	462,980	82.2%
Mathematics	291,075	190,345	65.4%
Mathematics and computer sciences, nec	8,221	0	0.0%
Physical sciences	1,368,262	645,838	47.2%
Astronomy	138,642	94,316	68.0%
Chemistry	439,611	181,351	41.3%
Physics	639,377	237,238	37.1%
Physical sciences, nec	150,632	132,933	88.3%
Psychology	560,647	4,542	0.8%
Biological aspects	1,124	0	0.0%
Social aspects	4,578	4,542	99.2%
Psychological sciences, nec	554,945	0	0.0%
Social sciences	212,207	120,393	56.7%
Anthropology	10,771	10,771	100.0%
Economics	31,742	13,866	43.7%
Political science	6,241	6,241	100.0%
Sociology	12,276	4,530	36.9%
Social sciences, nec	151,177	84,985	56.2%
Other sciences, nec	379,428	136,962	36.1%
Engineering	1,220,487	477,376	39.1%
Aeronautical engineering	44,466	0	0.0%
Astronautical engineering	9,933	0	0.0%
Chemical engineering	97,955	92,801	94.7%
Civil engineering	99,768	98,121	98.3%
Electrical engineering	162,452	62,868	38.7%
Mechanical engineering	45,346	4,159	9.2%
Metallurgy and materials engineering	241,430	132,349	54.8%
Engineering, nec	519,137	87,078	16.8%

nec = not elsewhere classified.

NOTES: Seven agencies are required to report data for this section of survey: Departments of Agriculture, Defense, Energy, Health and Human Services, and Homeland Security; National Aeronautics and Space Administration; and National Science Foundation. Basic research obligations of these seven agencies represented over 99% of total federal basic research obligations to universities and colleges in FY 2007.

SOURCE: National Science Foundation/Division of Science Resources Statistics, Survey of Federal Funds for Research and Development: FY 2007, 2008, and 2009.

36. In what national priority areas is NSF the lead source of US Government support for R&D?

Answer: The President's FY 2011 budget (Analytical Perspectives, Budget of the United States Government, Fiscal Year 2011) summarizes the Administration's priorities for federal research and development, as well as several multi-agency research activities coordinated through the National Science and Technology Council. NSF holds a lead role in priority STEM investments (science, technology, engineering and mathematics education), and is a major source of R&D funding in each of the three multi-agency activities highlighted in the Budget. NSF provides the largest or second-largest source of funding for both the Networking and Information Technology Research and Development (NITRD) Program and the National Nanotechnology Initiative (NNI). NSF provides substantial funding (following only NASA and Commerce) in support of the US Global Change Research Program.

NITRD coordinates agency research efforts in cyber security, high-end computing systems, advanced networking, software development, high-confidence systems, information management, and other information technologies. NNI focuses on R&D that creates materials, devices, and systems that exploit the fundamentally distinct properties of matter as it is manipulated at the nanoscale (roughly 1 to 100 nanometers), and has resulted in enabling breakthroughs in biomedical detection and treatment, advanced manufacturing, environmental monitoring and protection, sustainable energy production and energy conversion and storage, and more powerful electronic devices.

37. What does NSF consider to be the top accomplishment in each of the research directorates and offices and in education research in FY09?

Answer: Please see the following:

<u>Directorate for Biological Sciences (BIO)</u>
GFP: A Great Fascinating Protein and Its Path to the Nobel Prize

This year's Nobel Prize in chemistry to three researchers for their work on green fluorescent protein (GFP) has shone a spotlight on this workhorse of molecular and cellular biology. Like most tales of discovery, the story of GFP relies on a cast of characters each of whom contributed critical pieces to a puzzle that would unfold into one of the most revolutionary and widely used technologies in biology. This peculiar protein, originally isolated from a jellyfish, has not only transformed the way molecular and cellular biology are done, it has become an indispensable research tool that forms the scientific basis for many biotechnology companies in the United States and around the world.

In 1960, Osamu Shimomura came to the United States to pursue postdoctoral research on organisms that produce light or bioluminescence. He began his work on *Aequorea victoria*, a glowing jellyfish, and eventually purified two bioluminescent proteins from jellyfish "squeezate" (an odd, but appropriately descriptive, term he coined). His work, later funded by the NSF, identified aequorin, a protein that glows blue in the presence of calcium, and a green protein (later named green fluorescent protein), which only requires visible light to produce luminescence. It is this feature that has made GFP such an invaluable tool. Whereas Shimomura was primarily interested in understanding how the protein aequorin produces light, another investigator, Douglas Prasher, recognized GFP's potential value as a "reporter" that would allow researchers to visually observe a cell that has been programmed to produce the protein. Since GFP requires only visible light to glow, it is perfect for marking cells, because it will glow in any type of environment. On top of that, it is non-toxic and relatively small, so it doesn't get in the way of other cellular machinery. After Prasher sequenced the gene for GFP, two other researchers who would eventually share the Nobel Prize with Shimomura, Martin Chalfie and Roger Tsien, transformed the glowing GFP into a reliable multipurpose cellular marker that has been used in organisms from bacteria to rabbits and many things in between.

The first X-ray crystal structure of GFP was a result of collaboration between NSF-funded researchers S. James Remington and Tsien, and both laboratories continue to work on structural modifications that alter the fluorescent properties of the protein. In doing so, they have created proteins that fluoresce in a dizzying array of colors (yellow, red, orange, and more). By examining the structural features of the protein that determine the intensity and color of the light it emits, researchers have designed bioluminescent proteins that can be used in a wide range of biological applications. Another researcher funded through BIO's Division of Molecular and Cellular Biology, Rebekka Wachter, also works on designing fluorescent proteins with a focus on how the proteins "fold" and construct the light-generating center called the chromophore. An intriguing aspect of GFP is that the chromophore is comprised solely of amino acids already in the protein without the need for additional external factors. Understanding how fluorescent proteins work, at an atomic level, has allowed this biological novelty to become a full-fledged revolution in the study of living systems. A quick search for "GFP" in the scholarly database PubMed alone produces 15,897 hits.

Like many stories in the history of science, the path of GFP from curiosity to biotechnological revolution appears linear and progressive in hindsight. However, the value of this peculiar protein would have never been realized without a host of scientists, each with a genuine curiosity for the way the world works and a little bit of luck. It is this realization that makes the discovery and exploitation of GFP most compelling and remarkable. NSF funding has been critical to advancing our knowledge of GFP and how to apply it in making new discoveries about life.

Directorate for Computer and Information Science and Engineering (CISE)
Three Expeditions in Computing Established; Progress Made With Energy Efficiency and Cloud Computing

CISE's top research funding accomplishment in FY 2009 was the establishment of three new Expeditions in Computing. These projects support exploration of ideas that promise significant advances in our understanding of the computing frontier, while yielding great benefit to society. Funded at $2 million per year for five years, these projects represent some of the largest single investments made by the directorate. The 2009 Expeditions explore energy-efficient computers optimally designed for custom applications; new tools to make air travel safer and healthcare interventions more effective; and robotic 'bees' that lend a helping hand in search and rescue operations.

Regarding scientific accomplishments reported in 2009, two in particular stand out:

- Energy efficiency is the most significant challenge for continued integration of systems according to Moore's law, the principal driver behind the semiconductor industry. Carbon Nanotubes (CNTs) represent a significant departure from traditional silicon technologies and provide a very promising path towards solving this major challenge. In 2009, Stanford University researchers demonstrated, for the first time, the most advanced computing and storage elements using CNTs. This demonstration is a major milestone on the path toward Very-Large Scale Integrated systems since the first report of a rudimentary CNT transistor in 1998.
- Another important result, also from Stanford researchers, will harness the power of cloud computing while preserving the privacy of what is being computed. Researchers constructed the first fully homomorphic encryption scheme, solving a longstanding open problem first posed in 1978. This result means that one can encrypt input and send it to the cloud, which would compute the result in encrypted form, but not have any idea what input was used. The output would then be privately decrypted. The cloud not only does not know the input, it also does not know what was computed on it.

Directorate for Education and Human Resources (EHR)
Heightened Focus On Research and Evaluation For Improving STEM Education

EHR's top accomplishment in FY 2009 was a greatly heightened focus on the clarity of research and evaluation questions, and the related appropriately rigorous evaluation and research designs. The result is a very strong emphasis on high-quality evidence to enlighten practitioners and policy makers who are concerned with what works in improving STEM learning, for whom, and under what conditions. This is a result of changes in solicitations, the development of guiding frameworks and tools, and a focus on issues of research and evaluation in PI meetings as well as internal staff development and hiring. In Science magazine, Dr. Bruce Alberts states in his lead editorial for Volume 323, January 2009, that "...an education system must continually evolve to remain relevant to the interests and needs of each new generation. To achieve these ambitious goals, we will need much more emphasis on both science education and the science of education." The REESE and DRK-12 programs both address this need to explore the science of education.

Directorate for Engineering (ENG)
Improved Doppler Radar Network Promises to Improve Storm Detection

To overcome the predictive limitations of the current national weather radar system, the Engineering Research Center (ERC) for Collaborative Adaptive Sensing of the Atmosphere (CASA) is developing a network of small Doppler radars that scan the lowest level of the atmosphere, where severe weather forms.

The National Weather Service's (NWS) current state-of-the-art uses single Doppler velocities coupled with assumptions about the phenomena being observed to infer storm circulation. CASA, headquartered at the University of Massachusetts-Amherst, has made two major improvements to this approach. First, the better resolution of the CASA radar network brings immediate improvement to detection of severe weather, especially tornadoes. Second, CASA researchers use the full adaptive-sampling capabilities of the radars to directly image three-dimensional wind fields within storms.

When a tornadic storm hit Anadarko, Oklahoma on May 13, 2009, a CASA forecaster in a real time experiment at the NWS office was able to issue a "simulated warning" three minutes earlier than the NWS warning was issued. Since the current average lead time of the NWS for tornado warnings is 11 minutes, a 3-minute improvement in warning time is significant. The NWS field emergency managers later said that this degree of improvement in lead time would give them a critical advantage in their ability to protect the public. CASA expects that the detection lead time can be even further increased with greater experience and a more integrated use of CASA-developed software tools.

Directorate for Geosciences (GEO)
Future Cascadia Megathrust Fault Rupture Delineated by Episodic Tremor and Slip

James S. Chapman and Timothy I. Melbourne from Central Washington University have used a combination of GPS data and a coupling model to estimate that the Washington State Segment of the Cascadia plate margin is capable of generating a magnitude 8.9 earthquake, with significant seismic energy released close to major population centers. The Cascadia plate margin stretches from northern California to central British Columbia, and is characterized by convergence and subduction of the Juan De Fuca plate beneath the North American plate. Previous research has shown that the subduction zone is capable of producing magnitude-9 earthquakes along the megathrust fault approximately every 550 years. The NSF funded researchers have used GPS data from the Pacific Northwest Geodetic Array, the Plate Boundary Observatory, and the Western Canada Deformation Array to examine episodic tremor and slip events from 1997 to 2008, and have determined much of the future release from seismic energy from future large magnitude events will occur at depths exceeding 25 km, approximately 60 km inland of the Pacific coast. This indicates that significant seismic slip may occur near major population centers, such as the Seattle-Tacoma metropolitan area, rather than farther west as had been previously suggested. The results of this study and continued analysis of episodic tremor and slip events may provide a potentially valuable tool for mapping the future rupture depth, resultant magnitudes, and seismic hazards of future earthquakes on faults in this region. Their observations, published in the journal Geophysical Research Letters, argue for a reappraisal of Cascadia megathrust seismic hazards.

Office of Integrative Activities (IA)
New Perfluoropolyether Technology May Prove Transformative In Many Scientific Fields

Professor Joseph M. DeSimone and associates at the Science and Technology Center (STC) for Environmentally Responsible Solvents and Processes at the University of North Carolina – Chapel Hill have recently developed potentially transformative technology that is proving to have a significant impact in many fields, from medicine to space exploration to alternative energy options. The technology is based upon a material called perfluoropolyether (PFPEs) that is used for nanoscale pattern transfer and lithography. PFPEs exhibit positive attributes of both elastomers and rigid materials (such as glass) without the drawbacks of either. For example, PFPEs resist chemical attack and swelling by organic solvents; and can serve as precise molds for nanometer scale features.

A commercially available PFPE can be modified to incorporate a light-sensitive component. The process, called "PRINT®" can be used for nanoparticle fabrication. PRINT® technology is unique, providing for new sizes and shapes of particles that can be loaded with widely differing "cargoes" and the surface decorated with widely differing chemistries.

PRINT® technology has been used to demonstrate feasibility in a wide variety of applications including MRI imaging of internal organs; making artificial red blood cells (with the same size, shape and mechanical properties as natural RBCs); delivering therapeutic and diagnostic agents for treatment of cancer, notably cervical and breast cancer; patterning fuel cell membranes, interdigitated microelements for photovoltaic cells and for solar fuel production via photoelectrochemical cells; Lab-on-a-chip for on-demand production of radiochemicals for cancer treatment; and even a microfluidic device for an upcoming Mars exploration mission.

Directorate for Mathematical and Physical Sciences (MPS)
Significant Progress Made Towards Construction of the Advanced Technology Solar Telescope

NSF used a portion of its FY 2009 funding to jump-start work on the Advanced Technology Solar Telescope (ATST). Construction on the telescope will start in FY 2010. ATST will enable the study of magneto-hydrodynamic phenomena in the solar photosphere, chromosphere, and corona. Determining the role of magnetic fields in the outer regions of the Sun is crucial to understanding solar activity, which can affect life on Earth and may have an impact on the terrestrial climate. This project is a collaboration of scientists and engineers at more than 20 U.S. and international organizations, including, potentially, the Air Force Office of Scientific Research and groups in Germany, Italy, and the United Kingdom.

Office of Cyberinfrastructure (OCI)
Partnerships With Other NSF Directorates/Offices Led to Enhanced Cross-Foundation Investments

OCI's major accomplishment during FY 2009 was enhancement of partnerships with directorates across NSF, resulting in mutually beneficial support for the cyberinfrastructure (CI) that enables advances in science and engineering and for the computational scientists that develop and use that CI.

Specifically, the Petascale Application (PetaApps) activity, led by OCI but with participation from many of the other Directorates and Offices at the Foundation, was able to leverage $17.8 million for a total of $32.5 million in funding 58 proposals across disciplines spanning physics, chemistry, geosciences, biology, astrophysics and others. The PetaApps program supports projects that enable researchers to develop the future simulation and analysis tools that can use petascale computing and associated resources to advance the frontiers of scientific and engineering research beyond the current state-of-the-art.

In addition, OCI made significant investments in another cross-foundational activity, Cyber-enabled Discovery and Innovation (CDI). Finally, for the first time, OCI was able to participate in cross-foundational computational science education activities led by EHR such as CAREER, GRF and REU sites. Computational science is increasingly being recognized as a major contributor to the scientific method via its inherent association with simulation and modeling. It is imperative that the necessary skilled 21st century science and engineering workforce be developed to meet the growing demands of not only the research community but of the industrial and commercial sectors as they increasingly utilize cyberinfrastructure to accomplish their tasks.

Office of International Science and Engineering (OISE)
Taj Network Opens New Horizons Around the Globe

The OCI and OISE jointly funded Taj network has expanded to the Global Ring Network for Advanced Application Development (GLORIAD), wrapping another ring of light around the northern hemisphere for science and education. Taj now connects India, Singapore, Vietnam, and Egypt to the GLORIAD global infrastructure and dramatically improves existing U.S. network links with China and the Nordic region.

Taj promises far-reaching, stimulative, and sustainable benefits in global research and education (R&E) collaboration. It will serve knowledge disciplines from high energy physics, atmospheric and climate change science, to renewable energy research, to nuclear nonproliferation, genomics and medicine, economics, and history. The population of countries served by the NSF-sponsored GLORIAD program, funded since 1997, now exceeds half the globe.

In a unique public/private partnership with NSF, Tata Communications is providing a new billion bits per second (Gbps) service connecting science and education exchange points in Hong Kong, Singapore, Alexandria, Mumbai, Amsterdam, and Copenhagen (valued at $6 million) to interconnect vital national research and education networks in India and across Southeast Asia, including Singapore and Vietnam.

The new exchange point in Alexandria, Egypt affords new possibilities for science and education ties throughout the Middle East, Africa, and Central Asia and the Caucasus regions. Taj opens up new horizons for U.S. scientists, educators and students, enabling direct access to key research facilities in India, and, through new exchange points in Egypt and Singapore, improved connectivity for potentially millions of end-users conducting international collaborative research.

Office of Polar Programs (OPP)
International Polar Year Already Demonstrates Long-Lasting Impacts on Research

NSF investments in International Polar Year (IPY) research led to the discovery and publication in 2009 of heretofore unknown river valleys buried under as much as four kilometers (2.5 miles) of ice in East Antarctica; these investments also led to the creation of major elements of a circum-arctic observing system for improved forecasting of future climate change.

IPY marked the 50th anniversary of International Geophysical Year (IGY) 1957-58, in which unparalleled exploration of Earth and space led to discoveries in many fields of science that have forever changed the way we view the polar regions and their global significance. The U.S. National Academy of Sciences developed broad goals and objectives for U.S. IPY, and NSF, through the Office of Polar Programs, served as the lead federal agency for implementation.

As a result of IPY investments, legacies can be seen in:

- Partnerships: existing interagency and international partnerships were strengthened, and new partnerships were created;
- Data: data sharing and data management were improved; and
- Education & Outreach: students were involved in the international research venture, and the public was engaged through various outlets, which highlighted the importance of science and engineering in understanding Earth systems.

Synthesis activities will use IPY results to further our knowledge and understanding of: climate history and change and the resulting human impacts; ice sheet dynamics and history; and life in the cold and dark. NSF-funded IPY research is already contributing substantial new understanding of the interplay between the polar regions and the rest of the planet in global processes. Furthermore, important networks were built during IPY that will have long-lasting research impacts. The Arctic Observing Network is continuing to work on understanding the regional and global causes and consequences of present-day change, predicting future change, and developing adaptive responses. The Polar Earth Observing Network is collecting precise GPS and seismic data from new stations at remote sites to help model how much ice was lost over the 10,000 years since the last major ice age; these data will help researchers determine where, and at what rate, the ice sheets are changing in response to recent climate change.

<u>Directorate for Social, Behavioral, and Economic Sciences (SBE)</u>
SBE Research Recognized By Science Magazine: 'Breakthrough of the Year' Award for 2009

Science magazine's prestigious 'Breakthrough of the Year' award for 2009 recognized SBE-funded work on *Ardipithecus ramidus*. Discovered in the Middle Awash region of Ethiopia by an international scientific team, this early hominid revolutionized and challenged how scientists understand human evolution; unanimous consensus in the field is that these fossils are among the most important ever discovered. The fossils allow new interpretations of diet and habitat that were perhaps unexpected in this biped. First, the research confirms that early bipedalism did not occur because of an adaptation to more open habitats; the fauna recovered with *Ar. ramidus* indicate that she existed in woodland and forest. Second, she was an omnivore with a slight focus on fruit as indicated through multiple analyses. This differs significantly from foods eaten by later hominids, such as *Australopithecus afarensis* (Lucy), which likely ate abrasive or harder foodstuffs. These transformative findings have sparked controversy over where *Ar. ramidus* fits in the human family tree, and what it means for our relationship to other primate species.

38. What are the trends since 2000 in proposal pressure, proposal quality as measured by review scores, and success rates, including as a function of review score, across the various areas of NSF?

Answer: The chart below provides the data for proposals received, funding rates, and average review scores for awards and declines for the period 2000-2009.

FY	Proposal	Awards	Funding Rate	Average Award Score	Average Decline Score
2009	45,217	14,641	32%	4.14	3.11
2008	43,907	11,024	25%	4.20	3.20
2007	44,106	11,354	26%	4.20	3.19
2006	42,050	10,318	25%	4.22	3.22
2005	41,598	9,757	23%	4.22	3.20
2004	43,489	10,255	24%	4.22	3.14
2003	39,745	10,721	27%	4.19	3.12
2002	34,811	10,230	29%	4.18	3.13
2001	31,441	9,649	31%	4.18	3.16
2000	29,150	9,663	33%	4.19	3.16

Source: NSF Enterprise Information System, 4/3/2010.

There is a general decrease in average reviewer scores for awards with an increase in funding rate; however, the change is minimal. The trend in average award score indicates that there is no significant change in the quality of proposals awarded (as measured by average reviewer rating) as the funding rate increases. Similarly, there does not appear to be a relationship between funding rate and the average reviewer rating for declines.

39. NSF program managers use their judgment informed by peer review; what are five current examples of research grants that have proven to be major successes that were funded despite receiving review scores below 4?

Answer: As indicated in the question, NSF program managers are expected to use their judgment in making funding recommendations, informed by the external peer review. In developing a portfolio of funded projects, program managers take into account such factors as: different approaches to significant research and education questions; potential (with perhaps high risk) for transformational advances in a field; capacity building in a new and promising research area; or achievement of special program objectives.

As requested, below are five recent examples of funded projects that received an average reviewer rating less than 4.0. Since reviewer ratings are confidential (principal investigators are provided the ratings), the descriptions below are intentionally written so as not to identify the award.

- An award made to a recently formed small company received an average reviewer rating of 3.33. The goal of the initial NSF award was to develop a customer friendly system that would search, sort, and classify large quantities of information from commercial search engines or journal indexes. A subsequent award was made to incorporate trend detection in the system. Based on the initial award, several products were developed and the company grew from sales in 2001 of $100,000 to $16 million in 2009, with growth in number of employees from 7 in 2001 to 90 in 2009.

- A 5-year award made to an early career investigator received an average reviewer rating of 3.88. The supported basic research was on chemosensing, which led to new sensors and techniques to monitor mercury and lead in living cells. The investigator has won several awards for this research, as well as other federal and non-federal funding. This included funding to study metal accumulations in the brain using the tools developed in the NSF-funded program.

- A center award received an average reviewer rating of 3.70. The initial goal of the center was to support a multidisciplinary research program to establish the fundamental understanding necessary to develop new solvents in a large number of key manufacturing and service processes. This initial goal evolved into a more comprehensive vision to create a "revolution in sustainable technology through cutting-edge, integrated physical science/engineering; social science; and educational programs." The center reports that the NSF supported research has been instrumental in securing substantial additional funding, reporting $100 million in supplementary funds including collaborative projects, and an additional $240 million for cancer research. The center research has led to numerous patents, commercial applications, and advances in medical research.

- An award for teacher preparation received an average reviewer rating of 3.67. The goal of the project was to prepare highly qualified science and mathematics teachers to teach in high-need school districts. Students in the program work with university faculty to develop mathematics and science courses to become more student-centered, interactive, and collaborative. These students also conduct science discipline educational research projects and engage in field experiences with K-12 schools, working with teachers to prepare them to teach in high-need school districts. The program has led to a doubling in recruitment rates of science and mathematics teachers, as compared to statewide rates. The program has also been featured in national publications and forums.

• An award was made to support fundamental research in sensors that communicate wirelessly to perform tasks such as sensing and actuation. The average reviewer rating was 2.7. This research has led to significant advances in several domains, ranging from typical scenarios such as predictive maintenance on machinery, to more unique applications, such as monitoring and the environment, disaster management, energy efficiency, and monitoring physical or environmental conditions. Findings from this research led to the creation of a company that has become a leader and world-wide supplier in wireless sensor technology.

Future Perspective

40. What changes and challenges does the National Science Board predict for US science and technology in the coming years, and what are its recommendations to this committee to further strengthen US R&D?

Answer: In several recent reports, the Board has identified a number of changes and challenges for U.S. science and technology in the coming years, including:

National Science Board 2020 Vision for the National Science Foundation (NSB-05-142)
In December 2005, the Board issued this report in response to a request from Congress. The report identified new challenges in the "breathtaking advances" in the global scientific enterprise, including "unprecedented and continually increasing ability to observe the physical world, to simulate both natural and man-made systems in ways never before imagined, to efficiently store and analyze vast amounts of data, and to communicate information globally. The ability to understand and influence complex systems is changing – and will continue to change – human society more rapidly and far more profoundly than has been experienced in previous agricultural, industrial, and technological revolutions. .... the development of communications technology and systems worldwide allows new generations of professionals to live and work globally." To address these challenges, the report identified three strategic priorities for the Foundation:

1. Ensure the Nation maintains a position of eminence at the global frontier of fundamental and transformative research, emphasizing areas of greatest scientific opportunity and potential benefit;
2. Sustain a world-class S&E workforce and foster the scientific literacy of all our citizens; and
3. Build the Nation's basic research capacity through critical investments in infrastructure, including advanced instrumentation, facilities, cyberinfrastructure, and cutting-edge experimental capabilities.

Building a Sustainable Energy Future: U.S. Actions for an Effective Energy Economy Transformation (NSB-09-55)

In August 2009, the Board issued this report, which identified "a critical challenge to transform our current fossil fuel based energy economy to a stable and sustainable energy economy. This transformation must be achieved in a timely manner to increase U.S. energy independence, enhance environmental stewardship and reduce energy and carbon intensity, and generate continued economic growth through innovation in energy technologies and expansion of green jobs."

The Board recommended that "the U.S. Government should develop, clearly define, and lead a nationally coordinated research, development, demonstration, deployment, and education (RD3E) strategy to transform the U.S. energy system to a sustainable energy economy that is far less carbon intensive," through actions in all sectors to develop and encourage adoption of sustainable energy technologies.

Research and Development: Essential Foundation for U.S. Competitiveness in a Global Economy (NSB-08-3) and *Globalization of Science and Engineering Research* (NSB-10-3)
In these two companion pieces to Science and Engineering Indicators reports issued in 2008 and 2010, respectively, the Board identified critical challenges with respect to changes brought about by globalization of research and development (R&D). These critical challenges included: in 2008, a challenge with respect to U.S. high-tech industry's competitiveness in international markets and implications for highly skilled jobs at home; and in 2010, a challenge to the U.S. government to be attentive to developments in S&E capacity around the world and to take proactive steps to maintain our nation's competitive strength.

To ensure that transformative research receives adequate support, in 2008 the Board recommended that the federal government should take action to enhance the level of funding for, and the transformational nature of, basic research. In 2010, the Board recommended that to ensure that the U.S. remains a world leader in S&E research, the National Science Foundation – the only non-mission-oriented federal agency that funds S&E research – should assess its two merit review criteria for funding of S&E research to ensure that the criteria encourage the proposing and support of truly transformative research, and should modify the criteria and/or merit review process if the assessment finds modifications necessary to accomplish this goal. (The Board initiated a task force to review the Foundation's Merit Review criteria).

To assure that the quality of federally-funded research is world-leading, in 2010 the Board recommended that the Office of Science and Technology Policy (OSTP) in the Executive Office of the President, through the National Science and Technology Council mechanism, should engage all federal agencies involved with S&E research to: (a) develop means to assess or continue to assess the quality of their agency's supported research against international activities, and (b) identify and as appropriate make adjustments necessary to ensure that the agency's research is world-leading.

To enhance U.S. competitiveness in high technology, in 2008, the Board recommended that industry, government, the academic sector, and professional organizations should take action to encourage greater intellectual interchange between industry and academia. Industry researchers were encouraged to also participate as authors and reviewers for articles in open, peer-reviewed publications.

To better understand and respond to the impacts of globalization of R&D, in 2008 the Board recommended that to track the implications for the U.S. economy of the globalization of manufacturing and services in high-tech industry, the critical need for new data should be addressed expeditiously by relevant federal agencies. In 2010, the Board recommended that OSTP call for a President's Council on Innovation and Competitiveness as described in the 2007 America COMPETES Act (P.L. 110-69), to discuss issues of: (a) relationships between U.S. and foreign-supported R&D, to ensure continued vitality and growth of U.S. technical strength; (b) safeguarding national interests in intellectual property; (c) ensuring that the U.S. economy benefits from R&D supported abroad; and (d) assessing critical research areas for which the U.S. should be the global R&D leader.

41. In what areas of research does NSF anticipate major research discoveries in the next three years?

Answer: While it is not possible to predict when and where a major discovery will happen, targeting NSF investments in particular areas increases the odds that such areas will see more and larger discoveries. NSF awards likely to produce major discoveries in FY 2011-FY 2013 would most likely be products of investments made in FY 2008-FY 2010, such as Cyber-enabled Discovery and Innovation (new in FY 2008, $102.63 million estimated in FY 2010).

Additionally, in FY 2009 the American Recovery and Reinvestment Act provided significant increases in the National Nanotechnology Initiative, Networking and Information Technology Research and Development, and U.S. Global Change Research Program interagency activities. These one-time infusions of funds could produce major discoveries over the next few years.

Interagency Activity	FY 2009 Omnibus	FY 2009 ARRA	Total FY 2009 Funding	Percent of ARRA over Omnibus
NNI	$408.62	$101.20	$417.69	24.80%
NITRD	$1,011.62	$347.16	$1,090.48	34.30%
USGCRP	$269.26	$120.54	$319.06	44.80%

42. In what areas of research does NSF anticipate requirements for above average growth in funding and why?

Answer: The synergistic nature of research leads NSF to anticipate demand for funding to increase in fields which have received large increases in recent years. Demand in these fields will also rise once the trainees funded by these (and other workforce training awards, such as the Graduate Research Fellowships) begin seeking funding in these areas.

In FY 2011, NSF's Budget Request invests heavily in the existing Science and Engineering Beyond Moore's Law (50 percent increase) and cybersecurity (11 percent increase) activities, and the Cyberlearning Transforming Education (63 percent increase) and Science, Engineering and Education for Sustainability (16 percent increase) portfolios. The Request also supports transformative research into emerging high-payoff interdisciplinary areas, such as the intersection of the biological and physical sciences and the integration of nanotechnology and/or cyber-physical systems with traditional manufacturing industries.

These long-standing and rapidly increasing investments in the fields of computer science, cyberlearning, climate and energy science and engineering, bioengineering, and manufacturing could result in significant advances. While the outcomes and impacts of these investments on science and engineering knowledge will not be clear until FY 2014 or later, the investments are likely to have positive impact on the STEM workforce.

Authorizations and Obligations

43. Which programs, projects, or activities (PPA) proposed in the budget are unauthorized?

Answer: The Foundation's underlying authority, the National Science Foundation Act of 1950, as amended (P.L. 81-507), provides a general authorization for the agency. Thus, NSF has no unauthorized programs, projects, or activities. Activities having specific authorizations (e.g., America Competes Act) are outlined in the following table and can also be found in the FY 2011 NSF Budget Request under the tab titled *NSF Authorizations*.

National Science Foundation Current Authorizations

LEGISLATION	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	Authorization Levels FY 2009	FY 2010	FY 2011
			(Dollars in Millions)			
National Science Foundation Act of 1950 (P.L.81-507)[1]						
Scholarships and Graduate Fellowships				*within limits of funds made available for this purpose*		
General Authority				*within the limits of available appropriations*		
Administering Provisions				*to make such expenditures as may be necessary*		
International Cooperation and Coordination with Foreign Policy				*within the limit of appropriated funds*		
Contract Arrangements				*utilize appropriations available*		
America COMPETES Act (P.L.110-69)[2]	**$6,468.76**	**$2,401.66**	**$6,872.51**	**$7,326.00**	**$8,132.00**	
Account and Program Specific						
Research and Related Activities[3]	**$5,152.39**	**$2,062.64**	**$5,563.92**	**$5,742.30**	**$6,401.00**	
Experimental Program to Stimulate Competitive Research	*$133.00*	*$30.00*	*$147.12*	*$133.20*	*$147.80*	
Faculty Early Career Development (CAREER) Program	*$186.55*	*$166.20*	*$196.39*	*$183.60*	*$203.80*	
Graduate Research Fellowship Program	*$8.50*	*$46.94*	*$33.34*	*$10.00*	*$11.10*	
Integrative Graduate Education and Research Traineeship Program	*$38.36*	*$14.22*	*$39.37*	*$52.50*	*$58.30*	
Major Research Instrumentation	*$99.98*	*$99.85*	*$90.00*	*$123.10*	*$131.70*	
Professional Science Master's Degree Program	-	-	-	*$12.00*	*$15.00*	
Research Experiences for Undergraduates	*$74.47*	*$26.00*	*$66.66*	*$68.40*	*$75.90*	
Education and Human Resources	**$845.52**	**$85.00**	**$872.76**	**$995.00**	**$1,104.00**	
Advanced Technology Education	*$51.85*	-	*$64.00*	*$57.70*	*$64.00*	
Graduate Research Fellowship Program	*$107.00*	-	*$102.58*	*$107.20*	*$119.00*	
Integrative Graduate Education and Research Traineeship Program	*$25.41*	-	*$29.86*	*$30.10*	*$33.40*	
Mathematics and Science Education Partnerships	*$60.99*	*$25.00*	*$58.22*	*$111.00*	*$123.20*	
Science, Mathematics, Engineering, and Technology Talent Expansion Program	*$29.09*	-	*$31.53*	*$50.00*	*$55.00*	
Robert Noyce Scholarship Program	*$55.00*	*$60.00*	*$55.00*	*$115.00*	*$140.50*	
Major Research Equipment and Facilities Construction	**$160.76**	**$254.00**	**$117.29**	**$262.00**	**$280.00**	
Agency Operations and Award Management	**$294.09**	-	**$300.00**	**$309.76**	**$329.45**	
National Science Board	**$4.02**	-	**$4.54**	**$4.19**	**$4.34**	
Office of the Inspector General	**$11.99**	**$0.02**	**$14.00**	**$12.75**	**$13.21**	
Federal Ocean Acidification Research and Monitoring Act of 2009 (P.L.111-11)	**$10.37**	**$9.92**	*	**$6.00**	**$8.00**	**$12.00**
National Earthquake Hazards Reduction Program Reauthorization Act of 2003 (P.L.108-360)	**$56.00**	**$20.20**		**$42.77**		
Consolidated Appropriations Act, 2001 (P.L.106-554); Small Business Technology Transfer Program Reauthorization Act of 2001 (P.L.107-50)						
Small Business Innovation Research (SBIR) Program[4]	*$86.80*	*$44.85*		*2.5% of research funds (SBIR)*		
Small Business Technology Transfer (STTR) Program[5]	*$3.59*	*$5.05*		*0.3% of research funds (STTR)*		

[1] Organic language establishing NSF, authorization and appropriation language may not correspond to current accounts and programs.
[2] Authorizes agency funding for FYs 2008-10; authorizes agency, account, and various program levels.
[3] FY 2010 Estimate for Research and Related Activities excludes $54.0 million transferred to the U.S. Coast Guard.
[4] SBIR is currently authorized through January 31, 2010.
[5] STTR is currently authorized through January 31, 2010.
*Actual amounts will be reported after awards are completed.

44. For each such unauthorized PPA, what was the last authorization (public law reference); the last fiscal year of authorization; and the authorized funding level in the last fiscal year of authorization?

Answer: Please see response to question 43.

45. What was the amount of the appropriation provided for each such PPA for the last fiscal year in which it was authorized?

Answer: Please see response to question 43.

46. For each appropriation and by major program element, what have been the actual obligation rates by quarter for each of the last three fiscal years, and what are the planned obligation rates for fiscal years 2010 and 2011, also by quarter?

Answer: Table 1 shows the actual quarterly obligations for FY 2007 through FY 2009 by program. Table 2 shows the projected quarterly obligations for FY 2010 and FY 2011 by program for each appropriation. The quarterly obligations for FY 2010 and FY 2011 are expected to follow the same obligation patterns as those in prior fiscal years.

Table 1

NATIONAL SCIENCE FOUNDATION
FY 2007 - FY 2009 Actual Quarterly Obligations by Program
(Dollars in Millions)

	FY 2007 Q1	FY 2007 Q2	FY 2007 Q3	FY 2007 Q4	FY 2007 Actual	FY 2008 Q1	FY 2008 Q2	FY 2008 Q3	FY 2008 Q4	FY 2008 Actual	FY 2009 Omnibus Q1	FY 2009 Omnibus Q2	FY 2009 Omnibus Q3	FY 2009 Omnibus Q4	FY 2009 Omnibus Actual	FY 2009 ARRA Q3	FY 2009 ARRA Q4	FY 2009 ARRA Actual
Molecular & Cellular Biosciences	$9.35	$34.16	$35.20	$32.79	$111.50	$4.66	$32.07	$39.79	$35.76	$112.28	$6.67	$34.27	$32.73	$47.61	$121.28	$20.66	$40.67	$61.53
Integrative Organismal Systems	$2.44	$28.44	$38.93	$132.50	$202.31	$2.73	$36.84	$36.14	$124.33	$200.04	$7.94	$44.30	$54.86	$105.24	$212.34	$30.71	$31.00	$61.71
Environmental Biology	$13.99	$30.15	$32.18	$33.28	$109.60	$15.99	$26.70	$31.13	$36.89	$110.71	$18.53	$27.10	$24.59	$50.15	$120.37	$8.12	$55.11	$63.23
Biological Infrastructure	$6.66	$21.17	$26.94	$25.46	$80.23	$4.57	$22.18	$28.02	$55.09	$109.86	$3.18	$18.83	$22.76	$73.18	$117.95	$5.40	$33.34	$38.74
Emerging Frontiers	$1.22	$1.54	$19.91	$82.23	$104.90	$4.07	$22.73	$16.60	$39.33	$82.73	$5.17	$13.49	$24.81	$41.21	$84.68	$1.30	$33.50	$34.60
TOTAL, BIOLOGICAL SCIENCES	$33.66	$115.46	$153.16	$306.26	$608.54	$32.02	$140.52	$151.68	$291.40	$615.62	$41.49	$137.99	$159.75	$317.39	$656.62	$66.39	$193.62	$260.01
Computing & Communication Foundations	$3.70	$15.87	$29.52	$73.67	$122.76	$2.23	$15.55	$31.18	$94.67	$143.63	$2.82	$9.95	$13.78	$130.37	$156.92	$9.91	$31.26	$41.17
Information and Intelligent Systems	$13.98	$13.50	$15.07	$76.70	$119.25	$5.17	$18.34	$25.60	$90.22	$139.33	$3.82	$11.25	$15.80	$120.06	$150.93	$25.64	$35.53	$61.17
Computer & Network Systems	$6.48	$11.62	$22.54	$122.13	$162.77	$4.15	$25.72	$40.23	$104.06	$174.16	$12.05	$13.71	$44.09	$118.45	$188.30	$0.75	$91.50	$92.25
Information Technology Research	$17.21	$5.75	$19.18	$79.75	$121.89	$0.08	$0.62	$2.39	$75.05	$78.14	$0.27	$5.09	$2.82	$70.17	$78.35	$0.00	$40.41	$40.41
TOTAL, COMPUTER & INFO SCI. & ENGR	$41.37	$46.74	$86.31	$352.25	$526.67	$11.63	$60.23	$99.40	$364.00	$535.26	$18.96	$40.00	$76.49	$439.05	$574.50	$36.30	$198.70	$235.00
Chem., Bioengr., Environ., & Transport Systems	$4.15	$26.80	$26.49	$70.83	$128.27	$4.28	$27.63	$27.31	$73.59	$132.81	$9.87	$20.17	$25.40	$90.56	$146.00	$17.11	$43.46	$60.57
Civil, Mechanical, & Manufacturing Innovation	$6.22	$34.98	$35.10	$81.00	$157.30	$6.41	$36.06	$36.19	$82.45	$161.11	$25.96	$23.18	$39.95	$85.84	$174.93	$15.71	$42.25	$57.96
Electrical, Communications, & Cyber Systems	$2.52	$9.99	$34.47	$36.26	$83.24	$2.60	$10.30	$35.54	$35.17	$83.60	$2.27	$12.07	$24.69	$48.18	$87.21	$4.42	$41.15	$45.57
Industrial Innovation & Partnerships	$27.69	$25.50	$30.13	$37.46	$120.78	$28.55	$26.29	$31.06	$44.82	$130.72	$21.94	$34.71	$15.02	$40.45	$112.12	$23.09	$31.61	$54.70
Engineering Education & Centers	$2.35	$13.17	$22.56	$77.08	$115.16	$2.42	$13.58	$23.26	$76.76	$116.02	$2.20	$11.15	$14.84	$90.04	$118.23	$4.31	$27.87	$32.18
Emerging Frontiers in Research & Innovation	$0.00	$0.14	$0.08	$25.03	$25.25	$0.00	$0.07	$0.08	$25.07	$25.23	$0.02	$0.67	$0.16	$25.65	$26.50	$0.00	$14.00	$14.00
TOTAL, ENGINEERING	$42.93	$110.58	$148.83	$327.66	$630.00	$44.26	$113.93	$153.43	$337.87	$649.49	$62.26	$101.95	$120.06	$380.72	$664.99	$47.53	$217.45	$264.98
Atmospheric and Geospace Sciences	$86.62	$23.58	$29.18	$88.06	$227.44	$88.02	$23.96	$29.65	$88.40	$230.03	$81.85	$36.53	$18.15	$109.01	$245.54	$19.05	$49.15	$68.20
Earth Sciences	$17.43	$30.03	$55.83	$49.54	$152.83	$17.71	$30.51	$56.73	$52.87	$157.82	$16.55	$34.57	$45.62	$74.27	$171.01	$12.66	$72.56	$85.22
Integrative & Collaborative Educ. & Res.	$5.61	$5.33	$8.53	$37.35	$56.82	$5.70	$5.42	$8.67	$37.18	$56.96	$0.00	$3.58	$4.53	$53.36	$61.47	$9.60	$69.98	$79.58
Ocean Sciences	$27.29	$55.59	$75.35	$150.53	$308.76	$27.73	$56.49	$76.56	$152.28	$313.06	$29.34	$67.98	$64.99	$168.20	$330.51	$20.49	$93.51	$114.00
TOTAL, GEOSCIENCES	$136.95	$114.53	$168.89	$325.48	$745.85	$139.16	$116.38	$171.61	$330.73	$757.87	$127.74	$142.66	$133.29	$404.84	$808.53	$61.80	$285.20	$347.00
Astronomical Sciences	$37.71	$39.20	$70.24	$68.24	$215.39	$38.38	$39.89	$71.49	$68.14	$217.90	$63.33	$16.59	$55.21	$93.54	$228.67	$12.10	$73.70	$85.80
Chemistry	$10.78	$42.68	$68.67	$69.09	$191.22	$10.97	$43.44	$69.89	$70.32	$194.62	$9.71	$52.38	$52.51	$97.07	$211.67	$11.22	$76.14	$87.36
Materials Research	$7.54	$35.76	$130.83	$83.14	$257.27	$7.67	$36.39	$133.15	$85.33	$262.55	$9.06	$53.11	$65.02	$155.33	$282.52	$22.53	$85.64	$108.17
Mathematical Sciences	$5.39	$20.81	$98.74	$80.80	$205.74	$5.49	$21.18	$100.49	$84.60	$211.75	$2.96	$21.11	$73.53	$127.24	$224.84	$45.49	$51.85	$97.34
Physics	$41.69	$47.68	$98.18	$60.92	$248.47	$42.43	$48.53	$99.92	$60.77	$251.64	$42.32	$48.73	$80.10	$91.32	$262.47	$25.28	$71.02	$96.30
Multidisciplinary Activities	$1.07	$5.28	$5.53	$20.76	$32.64	$1.09	$5.37	$5.63	$20.58	$32.67	$0.00	$1.93	$3.41	$28.36	$33.70	$0.00	$0.00	$0.00
TOTAL, MATHEMATICAL & PHYSICAL SCI	$104.18	$191.41	$472.19	$382.95	$1,150.73	$106.03	$194.80	$480.56	$389.74	$1,171.13	$127.38	$193.85	$329.78	$592.86	$1,243.87	$104.52	$370.45	$474.97
Social and Economic Sciences	$9.28	$20.22	$17.23	$53.13	$99.86	$9.86	$21.48	$18.30	$43.77	$93.40	$2.14	$15.88	$22.32	$54.48	$94.82	$5.62	$35.48	$41.10
Behavioral and Cognitive Sciences	$7.67	$9.89	$17.13	$49.95	$84.64	$8.15	$10.50	$18.19	$50.45	$87.30	$3.21	$10.17	$23.87	$50.87	$88.12	$4.97	$38.19	$43.16
Office of Multidisciplinary Activities	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$18.51	$18.51	$0.00	$0.00	$0.00	$18.91	$18.91	$0.00	$0.00	$0.00
Science Resources Statistics	$2.36	$4.75	$3.78	$19.15	$30.04	$2.51	$5.05	$4.01	$17.09	$28.66	$4.49	$2.21	$18.13	$13.88	$38.71	$0.00	$0.71	$0.71
TOTAL, SOCIAL, BEHAVIORAL & ECON SCI	$19.31	$34.86	$38.14	$122.23	$214.54	$20.51	$37.03	$40.51	$129.82	$227.87	$9.84	$28.26	$64.32	$138.14	$240.56	$10.59	$74.38	$84.97
OFFICE OF CYBERINFRASTRUCTURE	$0.23	$1.12	$16.18	$164.89	$182.42	$0.23	$1.14	$16.42	$167.36	$185.15	$1.36	$2.30	$10.13	$185.44	$199.23	$7.40	$72.60	$80.00
OFFICE OF INTERNATL SCI & ENGR	$2.09	$1.63	$7.15	$29.49	$40.36	$2.47	$8.46	$8.46	$28.37	$47.77	$4.40	$2.19	$5.96	$34.90	$47.45	$7.98	$6.00	$13.98

Totals may not add due to rounding

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NATIONAL SCIENCE FOUNDATION
FY 2007 - FY 2009 Actual Quarterly Obligations by Program Subactivity
(Dollars in Millions)

	FY 2007 Q1	FY 2007 Q2	FY 2007 Q3	FY 2007 Q4	FY 2007 Actual	FY 2008 Q1	FY 2008 Q2	FY 2008 Q3	FY 2008 Q4	FY 2008 Actual	FY 2009 Omnibus Q1	FY 2009 Omnibus Q2	FY 2009 Omnibus Q3	FY 2009 Omnibus Q4	FY 2009 Omnibus Actual	FY 2009 ARRA Q3	FY 2009 ARRA Q4	FY 2009 ARRA Actual
Arctic Sciences	$7.98	$23.13	$13.88	$44.28	$89.27	$8.15	$23.63	$14.18	$45.23	$91.19	$8.32	$16.40	$22.07	$51.81	$98.60	$22.00	$69.86	$91.86
Antarctic Sciences	$1.05	$7.56	$10.60	$37.44	$56.65	$1.69	$12.17	$17.06	$28.14	$59.06	$5.92	$6.30	$15.95	$40.47	$68.64	$17.58	$46.95	$64.53
Antarctic Infrastructure and Logistics	$20.90	$60.57	$36.35	$115.95	$233.76	$8.15	$23.63	$14.18	$194.12	$240.08	$29.00	$20.00	$15.00	$182.66	$246.66	$0.00	$15.50	$15.50
Polar Environment, Health, and Safety	$0.20	$0.07	$0.19	$5.33	$5.79	$0.20	$0.07	$0.19	$5.44	$5.91	$0.00	$0.27	$0.06	$5.79	$6.12	$0.00	$0.00	$0.00
USCG Polar Icebreaking	$54.00	$0.00	$0.00	$0.00	$54.00	$50.89	$0.00	$0.00	$0.00	$50.89	$15.00	$23.08	$10.00	$5.44	$53.52	$0.00	$0.00	$0.00
TOTAL, OFFICE OF POLAR PROGRAMS	$84.13	$91.33	$61.02	$203.00	$439.47	$69.09	$59.50	$45.61	$272.93	$447.13	$58.24	$66.05	$63.08	$286.17	$473.54	$39.58	$132.31	$171.89
EPSCoR Activities	$3.03	$15.86	$43.36	$39.86	$102.11	$3.56	$18.64	$50.96	$46.84	*$120.00*	*$0.39*	*$8.85*	*$13.81*	$109.95	$136.00	$0.00	$30.00	$30.00
Non-EPSCoR Activities	$4.20	$8.03	$0.92	$104.19	$117.34	$3.38	$6.47	$0.74	$83.89	$94.48	$0.62	$76.00	$3.57	$28.39	$108.58	$0.00	$99.85	$99.85
TOTAL, INTEGRATIVE ACTIVITIES	$7.23	$23.89	$44.28	$144.05	$219.45	$6.94	$25.10	$51.70	$130.74	$214.48	$1.01	$84.85	$17.38	$138.34	$241.58	$0.00	$129.85	$129.85
U.S. ARCTIC RESEARCH COMMISSION	$1.45	$0.00	$0.00	$0.00	$1.45	$1.47	$0.00	$0.00	$0.00	$1.47	$0.00	$0.00	$1.50	$0.00	$1.50	$0.00	$0.00	$0.00
TOTAL, RESEARCH & RELATED ACTIVITIES	$473.53	$731.55	$1,196.15	$2,357.22	$4,758.44	$433.81	$757.08	$1,219.39	$2,442.95	$4,853.25	$452.68	$800.10	$981.74	$2,917.85	$5,152.37	$382.09	$1,680.56	$2,062.65
Undergraduate Education	$5.88	$13.67	$47.96	$137.25	$204.96	$7.29	$17.19	$59.44	$170.09	$254.00	$3.69	$11.68	$34.82	$232.89	$283.08	$69.38	$15.62	$85.00
Graduate Education	$30.67	$62.35	$18.32	$44.56	$155.90	$31.40	$63.83	$18.75	$45.61	$159.59	$30.82	$10.50	$89.99	$50.36	$181.67	$0.00	$0.00	$0.00
Human Resource Development	$4.52	$7.01	$29.85	$84.42	$125.80	$5.04	$7.82	$33.31	$94.20	$140.37	$13.69	$8.49	$25.80	$106.10	$154.08	$0.00	$0.00	$0.00
Res. on Learning in Formal & Informal Settings	$12.21	$13.39	$43.17	$140.22	$208.99	$12.40	$13.60	$43.85	$142.44	$212.30	$3.98	$19.82	$43.22	$159.66	$226.68	$0.00	$0.00	$0.00
TOTAL, EDUCATION & HUMAN RESOURCES	$53.28	$96.62	$139.30	$406.45	$695.65	$58.69	$106.43	$153.44	$447.70	$766.26	$52.18	$50.49	$193.83	$549.01	$845.51	$69.38	$15.62	$85.00
MAJOR RESEARCH EQUIPMENT & FACILITIES CONSTRUCTION																		
Alaska Regional Research Vessel	$0.00	$0.00	$0.00	$2.58	$2.58	$0.00	$0.00	$0.00	$1.48	$1.48	$0.00	$0.00	$14.13	$0.00	$14.13	$148.07	$0.00	$148.07
Atacama Large Millimeter Array	$5.90	$26.00	$32.32	$0.08	$64.30	$15.01	$60.00	$27.00	$0.06	$102.07	$0.05	$41.00	$0.00	$41.20	$82.25	$0.00	$105.93	$105.93
Adv. Laser Interferometer Grav. Wave Obs.	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$32.75	$0.00	$32.75	$17.00	$0.00	$34.43	$0.00	$51.43	$0.00	$0.00	$0.00
Advanced Technology Solar Telescope	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
EarthScope	$0.00	$0.25	$0.00	$25.68	$25.93	$2.00	$1.14	$1.07	$0.00	$4.21	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
IceCube Neutrino Observatory	$0.58	$1.00	$22.78	$0.02	$24.38	$1.00	$0.04	$12.91	$4.79	$18.74	$0.00	$0.06	$7.47	$4.32	$11.85	$0.00	$0.00	$0.00
Integrated Ocean Drilling Program	$0.00	$27.00	$11.81	$4.02	$42.83	$0.02	$0.00	$0.00	$0.00	$0.02	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
South Pole Station Modernization	$0.80	$2.50	$0.23	$2.66	$6.19	$3.95	$0.04	$0.00	$3.58	$7.57	$0.00	$0.43	$0.00	$0.67	$1.10	$0.00	$0.00	$0.00
TOTAL MAJOR RES EQUIP & FAC CONSTR	$7.28	$56.75	$67.13	$35.05	$166.21	$7.31	$56.97	$67.39	$35.18	$166.85	$17.05	$41.48	$56.04	$46.19	$160.76	$148.07	$105.93	$254.00
AGENCY OPERATIONS AND AWARD MANAGEMENT																		
Personnel Compensation & Benefits	$57.45	$19.13	$44.10	$40.25	$160.93	$40.87	$41.47	$47.67	$44.27	$174.28	$42.49	$45.43	$51.84	$46.85	$186.61	$0.00	$0.00	$0.00
Rent & Communications	$10.16	$6.56	$4.85	$5.15	$26.72	$6.31	$18.22	$0.48	$1.93	$26.94	$10.39	$2.07	$11.63	$2.46	$26.55	$0.00	$0.00	$0.00
Other	$8.03	$13.58	$12.03	$27.20	$60.84	$38.67	-$15.12	$21.06	$36.20	$80.82	$4.24	$18.71	$18.64	$39.34	$80.93	$0.00	$0.00	$0.00
TOTAL AGENCY OPS AND AWARD MGMT	$75.64	$39.27	$60.98	$72.60	$248.49	$85.85	$44.57	$69.21	$82.40	$282.04	$57.12	$66.21	$82.11	$88.65	$294.09	$0.00	$0.00	$0.00
OFFICE OF THE INSPECTOR GENERAL	$3.13	$1.19	$2.39	$5.21	$11.92	$3.11	$1.18	$2.37	$5.17	$11.83	$3.21	$2.36	$2.88	$3.54	$11.99	$0.00	$0.02	$0.02
OFFICE OF THE NATIONAL SCIENCE BOARD	$1.13	$0.72	$0.58	$1.22	$3.65	$1.18	$0.75	$0.61	$1.28	$3.82	$0.50	$0.73	$0.84	$1.95	$4.02	$0.00	$0.00	$0.00
TOTAL, NSF	$613.99	$926.10	$1,466.53	$2,877.76	$5,884.37	$589.95	$966.99	$1,512.42	$3,014.69	$6,084.04	$582.74	$961.37	$1,317.44	$3,607.19	$6,468.76	$599.54	$1,802.13	$2,401.66

Totals may not add due to rounding.

Table 2

NATIONAL SCIENCE FOUNDATION
FY 2010 and FY 2011 Projected Obligation Plan by Program Subactivity

(Dollars in Millions)

	FY 2010 Current Plan	FY 2010 Q1	FY 2010 Q2	FY 2010 Q3	FY 2010 Q4	FY 2011 Request	FY 2011 Q1	FY 2011 Q2	FY 2011 Q3	FY 2011 Q4
Molecular & Cellular Biosciences	$125.59	$10.53	$38.48	$39.65	$36.93	$133.69	$11.21	$40.96	$42.21	$39.32
Integrative Organismal Systems	$216.25	$2.61	$30.40	$41.61	$141.63	$226.70	$2.73	$31.87	$43.62	$148.47
Environmental Biology	$142.55	$18.20	$39.21	$41.85	$43.29	$155.59	$19.86	$42.80	$45.68	$47.24
Biological Infrastructure	$126.86	$10.53	$33.47	$42.60	$40.26	$145.63	$12.09	$38.43	$48.90	$46.21
Emerging Frontiers	$103.29	$1.20	$1.52	$19.60	$80.97	$106.20	$1.24	$1.56	$20.16	$83.25
TOTAL, BIOLOGICAL SCIENCES	$714.54	$43.07	$143.08	$185.32	$343.07	$767.81	$47.13	$155.61	$200.57	$364.50
Computing & Communication Foundations	$170.35	$5.13	$22.02	$40.96	$102.23	$186.95	$5.63	$24.17	$44.96	$112.19
Information and Intelligent Systems	$163.32	$19.15	$18.49	$20.64	$105.05	$227.08	$26.62	$25.71	$28.70	$146.05
Computer & Network Systems	$204.42	$8.14	$14.59	$28.31	$153.38	$189.74	$7.55	$13.55	$26.27	$142.37
Information Technology Research	$80.74	$11.40	$3.81	$12.70	$52.83	$80.74	$11.40	$3.81	$12.70	$52.83
TOTAL, COMPUTER & INFORMATION SCIENCE & ENGINEERING	$618.83	$43.82	$58.91	$102.62	$413.48	$684.51	$51.21	$67.23	$112.63	$453.44
Chemical, Bioengineering, Environmental, & Transport Systems	$156.82	$5.07	$32.77	$32.39	$86.60	$169.07	$5.47	$35.32	$34.92	$93.36
Civil, Mechanical, & Manufacturing Innovation	$188.00	$7.43	$41.81	$41.95	$96.81	$206.50	$8.17	$45.92	$46.08	$106.34
Electrical, Communications, & Cyber Systems	$94.00	$2.85	$11.28	$38.93	$40.95	$103.00	$3.12	$12.36	$42.65	$44.87
Industrial Innovation & Partnerships	$152.00	$34.85	$32.09	$37.92	$47.14	$177.70	$40.74	$37.52	$44.33	$55.11
Engineering Education & Centers	$124.11	$2.53	$14.19	$24.31	$83.07	$138.40	$2.82	$15.83	$27.11	$92.64
Emerging Frontiers in Research & Innovation	$29.00	$0.00	$0.16	$0.09	$28.75	$31.00	$0.00	$0.17	$0.10	$30.73
TOTAL, ENGINEERING	$743.93	$52.73	$132.30	$175.59	$383.31	$825.67	$60.32	$147.12	$195.19	$423.04
Atmospheric and Geospace Sciences	$259.80	$98.94	$26.93	$33.33	$100.59	$280.80	$106.94	$29.11	$36.03	$108.72
Earth Sciences	$183.00	$20.87	$35.96	$66.85	$59.32	$199.00	$22.70	$39.10	$72.70	$64.51
Integrative and Collaborative Education and Research	$97.92	$9.67	$9.19	$14.70	$64.37	$97.60	$9.64	$9.16	$14.65	$64.16
Ocean Sciences	$348.92	$30.84	$62.82	$85.15	$170.11	$377.89	$33.40	$68.04	$92.22	$184.23
TOTAL, GEOSCIENCES	$889.64	$160.32	$134.90	$200.03	$394.38	$955.29	$172.67	$145.41	$215.59	$421.62
Astronomical Sciences	$245.69	$43.01	$44.71	$80.12	$77.84	$251.77	$44.08	$45.82	$82.10	$79.77
Chemistry	$233.73	$13.18	$52.17	$83.94	$84.45	$247.56	$13.96	$55.25	$88.90	$89.45
Materials Research	$302.67	$8.87	$42.07	$153.92	$97.81	$319.37	$9.36	$44.39	$162.41	$103.21
Mathematical Sciences	$241.38	$6.32	$24.41	$115.84	$94.80	$253.46	$6.64	$25.64	$121.64	$99.54
Physics	$290.04	$48.66	$55.66	$114.61	$71.11	$298.19	$50.03	$57.22	$117.83	$73.11
Multidisciplinary Activities	$38.33	$1.26	$6.20	$6.49	$24.38	$39.56	$1.30	$6.40	$6.70	$25.16
TOTAL, MATHEMATICAL & PHYSICAL SCIENCES	$1,351.84	$121.31	$225.23	$554.92	$450.39	$1,409.91	$125.36	$234.72	$579.59	$470.23
Social and Economic Sciences	$99.05	$9.20	$20.06	$17.09	$52.70	$104.12	$9.68	$21.08	$17.97	$55.40
Behavioral and Cognitive Sciences	$94.58	$8.57	$11.05	$19.14	$55.82	$99.21	$8.99	$11.59	$20.08	$58.55
Office of Multidisciplinary Activities	$27.00	$0.00	$0.00	$0.00	$27.00	$36.72	$0.00	$0.00	$0.00	$36.72
Science Resources Statistics	$34.62	$2.72	$5.47	$4.36	$22.07	$28.74	$2.26	$4.54	$3.62	$18.32
TOTAL, SOCIAL, BEHAVIORAL & ECONOMIC SCIENCES	$255.25	$20.50	$36.58	$40.59	$157.58	$268.79	$20.92	$37.22	$41.66	$168.99
OFFICE OF CYBERINFRASTRUCTURE	$214.28	$0.27	$1.32	$19.01	$193.69	$228.07	$0.29	$1.40	$20.23	$206.15
OFFICE OF INTERNATIONAL SCIENCE & ENGINEERING	$47.83	$2.48	$1.93	$8.47	$34.95	$53.26	$2.76	$2.15	$9.44	$38.92
Arctic Sciences	$106.31	$9.50	$27.55	$16.53	$52.73	$111.36	$9.95	$28.85	$17.31	$55.24
Antarctic Sciences	$71.08	$1.32	$9.49	$13.30	$46.98	$75.18	$1.39	$10.03	$14.07	$49.69
Antarctic Infrastructure and Logistics including	$266.76	$23.85	$69.12	$41.48	$132.32	$280.18	$25.05	$72.60	$43.56	$138.98
Polar Environment, Health, and Safety	$7.01	$0.24	$0.08	$0.23	$6.45	$7.27	$6.25	$0.09	$0.24	$6.69
USCG Polar Icebreaking	$0.00	$0.00	$0.00	$0.00	$0.00	$54.00	$54.00	$0.00	$0.00	$0.00
TOTAL, OFFICE OF POLAR PROGRAMS	$451.16	$34.91	$106.23	$71.54	$238.48	$527.99	$90.65	$111.57	$75.18	$250.59
EPSCoR Activities	$147.12	$4.37	$22.85	$62.47	$57.43	$154.36	$4.58	$23.98	$65.55	$60.26
Non-EPSCoR Activities	$127.92	$4.58	$8.75	$1.00	$113.58	$141.57	$5.07	$9.69	$1.11	$125.70
TOTAL, INTEGRATIVE ACTIVITIES	$275.04	$8.94	$31.61	$63.48	$171.01	$295.93	$9.65	$33.66	$66.66	$185.96
UNITED STATES ARCTIC RESEARCH COMMISSION	$1.58	$0.00	$0.00	$0.00	$1.58	$1.60	$1.60	$0.00	$0.00	$0.00
TOTAL, RESEARCH AND RELATED ACTIVITIES	$5,563.92	$488.35	$872.09	$1,421.55	$2,781.94	$6,018.83	$582.56	$936.10	$1,516.74	$2,983.43
Undergraduate Education	$292.41	$8.39	$19.79	$68.42	$195.81	$289.98	$8.32	$19.62	$67.85	$194.18
Graduate Education	$181.44	$35.69	$72.56	$21.32	$51.86	$185.26	$36.45	$74.09	$21.77	$52.95
Human Resource Development	$156.91	$5.64	$8.74	$37.23	$105.30	$168.91	$6.07	$9.41	$40.08	$113.35
Research on Learning in Formal and Informal Settings	$242.00	$14.14	$15.50	$49.99	$162.37	$247.85	$14.48	$15.88	$51.20	$166.29
TOTAL, EDUCATION & HUMAN RESOURCES	$872.76	$63.86	$116.60	$176.96	$515.33	$892.00	$65.31	$119.01	$180.90	$526.78
MAJOR RESEARCH EQUIPMENT & FACILITIES CONSTRUCTION	$117.29	$5.14	$40.05	$47.37	$24.73	$165.19	$7.24	$56.40	$66.72	$34.83
AGENCY OPERATIONS AND AWARD MANAGEMENT	$300.00	$91.32	$47.41	$73.62	$87.65	$329.19	$100.20	$52.02	$80.78	$96.18
OFFICE OF THE INSPECTOR GENERAL	$14.00	$3.68	$1.40	$2.81	$6.12	$14.35	$3.77	$1.43	$2.88	$6.27
OFFICE OF THE NATIONAL SCIENCE BOARD	4.54	1.41	0.90	0.72	1.52	$4.84	$1.50	$0.95	$0.77	$1.62
TOTAL, NATIONAL SCIENCE FOUNDATION	$6,872.51	$653.74	$1,078.44	$1,723.03	$3,417.29	$7,424.40	$760.57	$1,165.93	$1,848.78	$3,649.12

GLOBE

47. For each directorate and office what are the end-of-year FTE data for each of the last five fiscal years, including both rotators and regular employees and how many of each?

Answer: The below tables include NSF's full-time equivalent (FTE) and Intergovernmental Personnel Act (IPA) usage by directorate for FY 2005 through FY 2009. The costs associated with the FTE employees are funded out of the Agency Operations and Award Management (AOAM) account while the costs associated with the IPAs are funded by the Research and Related Activities (R&RA) and Education and Human Resources (EHR) accounts.

FTE Usage by Directorate

Directorate	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
BIO	106	105	111	106	118
BFA	129	132	133	149	148
CISE	55	58	63	65	63
EHR[1]	126	123	117	117	134
ENG	111	108	110	108	124
GEO	94	99	98	96	102
IRM	162	163	164	169	169
MPS	118	115	126	127	127
SBE	99	98	104	105	107
O/D[1]	171	162	170	181	176
Subtotal, Reg FTE	*1,171*	*1,164*	*1,196*	*1,224*	*1,266*
Student	29	32	32	32	34
Total, NSF	**1,200**	**1,195**	**1,228**	**1,256**	**1,300**

Totals may not add due to rounding.

[1] In FY 2007 9 FTE were transferred with EPSCoR from EHR to O/D.

IPA Usage by Directorate

(Shown in Full-Time Equivalents)

Directorate	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
BIO	19	18	23	20	21
BFA	-	-	0	1	1
CISE	19	19	24	24	24
EHR	30	26	23	23	23
ENG	21	23	30	25	29
GEO	17	17	20	23	23
IRM	1	1	3	2	1
MPS	18	20	23	21	21
SBE	4	6	11	8	10
OD	4	6	9	11	12
Total, NSF	**134**	**135**	**167**	**157**	**164**

Totals may not add due to rounding.

48. For fiscal year 2010, for each directorate and office, what are the current on-board FTE levels, the numbers of rotators, and how many FTEs are permanent part time?

Answer: The table below represents a snapshot of current NSF on-board FTE by directorate.

FY 2010 NSF Workforce

Current Onboard Staff by Type of Appointment as of 02/27/2010

Directorate	Full Time Permanent	Full Time Temporary[1]	Part Time Permanent	Part Time Temporary[1]	Reimbursable Details In	VSEE[2]	Total Onboard FTE levels (including PT FTE)	Count of Experts & Consultants[3]	Count of Students[4]	IPA assignments FYTD[5]
BFA	143	2	2	2	-	-	147	2	-	2
BIO	85	18	-	-	-	14	117	4	-	22
CISE	55	6	-	-	-	3	64	4	-	28
EHR	99	18	-	-	-	10	127	19	-	31
ENG	102	17	-	1	-	1	122	14	-	32
GEO	85	9	2	-	1	5	101	6	-	21
IRM	171	-	-	-	-	-	171	1	-	3
MPS	103	20	1	-	-	8	132	10	-	21
O/D	170	14	-	-	1	1	186	8	-	16
SBE	92	9	-	-	-	6	107	1	-	11
Total	**1,105**	**113**	**5**	**3**	**2**	**48**	**1,273**	**69**	**72**	**187**

Totals may not add due to rounding.

Excludes NSB and OIG.

[1] Employees with a time limited appointment.

[2] Visiting Scientists, Engineers, & Educators (all are full-time).

[3] Experts and consultants serve on an intermittent basis; Each onboard represents approximate usage of less than 0.25 FTE per year. (maximum estimated current FTE level: 17).

[4] Students are not reported by directorate, and are accounted for as a total category. Because of varying work schedules, student FTE onboard level to date (37.8) is significantly lower than onboard count.

[5] IPA assignments to date counts the number of IPA assignments of 2/27/2010.

49. For fiscal years 2010 and 2011, for each directorate and office, what are the anticipated end-of-year on-board FTE levels, the numbers of rotators, and how many FTEs will be permanent part time?

Answer: The table below demonstrates projected annualized usage by employee type for FY 2010 and FY 2011. Of the FTE projected below, 2.5 FTE will be for permanent part time positions. The estimated FY 2011 annualized usage by directorate is based on current allocations by directorate. Final FY 2011 allocations will occur after FY 2011 Current Plan approval.

NSF Projected Annualized Usage, FY 2010-2011

Data as of 02/27/2010

Directorate	FY 2010				FY 2011			
	FTE[1]	IPA[2]	Students[3]	FY 2010 Total	FTE[1]	IPA[2]	Students[3]	FY 2011 Total
BFA	147	1	-	148	157	1	-	158
BIO	117	23	-	140	119	26	-	145
CISE	67	30	-	97	73	31	-	104
EHR	130	31	-	161	130	31	-	161
ENG	125	30	-	155	121	33	-	154
GEO	103	25	-	128	108	27	-	135
IRM	173	3	-	176	182	3	-	185
MPS	131	30	-	161	135	32	-	167
O/D[4]	184	26	-	210	215	26	-	241
SBE	108	12	-	120	110	12	-	122
Total	1,285	211	37	1,532	1,350	222	40	1,612

Totals may not add due to rounding.

Excludes NSB and OIG.

[1] Includes Visiting Scientists, Engineers, & Educators (VSEE).

[2] This figure is the number of estimated IPA agreements for FY 2010 and FY 2011 included in the FY 2011 Congressional Request.

[3] Students are not reported by directorate, and are accounted for as a total category.

[4] O/D includes OCI, OISE, & OPP.

50. What are the similar FTE data as requested above for all political appointee positions?

Answer: Political appointee positions at NSF consist of the Director, the Deputy Director, and the 24 members of the National Science Board (NSB), for a total of 26 political appointees.

The Director and Deputy Director each occupy one full FTE, while the 24 NSB members occupy six FTE, on the assumption that one intermittent work schedule equates to 0.25 FTE.

51. What are the average annual costs of a fully-loaded FTE in fiscal years 2010 and 2011 and separately what are these costs for regular FTEs and for rotators?

Answer: The below table includes the average cost of a fully loaded full-time equivalent (FTE) employee, which includes both regular and student FTE; a fully loaded Intergovernmental Personnel Act (IPA) employee; and the combined average for FY 2010 and FY 2011. The average cost of a fully loaded FTE includes salaries and benefits, space rental and utility costs, travel, training, equipment, and supplies. The average cost of an IPA includes IPA compensation, space rental and utility costs, lost consultant costs, per diem expenses, and travel.

Average Cost Per FTE/IPA

Position Type	FY 2010 Estimate	FY 2011 Request
FTE	$177,000	$178,000
IPA	$236,000	$235,000
Combined Average	$185,000	$186,000

Ranking Member Frank R. Wolf
Questions for the Record

STEM Education

1. **Your overall budget increase is for over 7% for FY11, yet the increase in your Education and Human Resources account is just 2.2%. This has been a consistent pattern over the last few years. Why have both this administration and the previous administration prioritized research over education?**

   Answer: Because the integration of research and education is a defining characteristic of NSF, the individual budget lines do not fully capture NSF's catalytic role in education. For example, over one-third of the investments under NSF's strategic goal for learning are funded throughout the Research and Related Activities (R&RA) account. In addition, there are educational impacts associated with virtually all NSF research awards – from the support of graduate students and undergraduates, to links to curricula and teaching activities, and activities to promote public awareness generally.

2. **How are you measuring the results of your education programs, and are you finding that investments in education programs have less impact than research programs?**

   Answer: STEM education programs are principally managed by the Directorate for Education and Human Resources (EHR), but a number of NSF research directorates sponsor their own education programs that are discipline-based. With respect to evaluation of programs, all NSF directorates utilize a standard evaluation mechanism, Committees of Visitors, whereby experts external to the Foundation review (on a three-year cycle) agency research and education programs to assess the quality and integrity of operations and management processes, and review the results generated by program awardees. For all EHR programs, independently-contracted external evaluations (formative, monitoring, outcome and impact) are conducted regularly. All EHR programs have OMB-approved metrics to assess program impact. Because many of the EHR programs are research and development programs, we emphasize the importance of developing high-quality evidence about how the materials, models and tools that are developed work, for whom, and under what conditions. It is difficult to compare the relative impact and effectiveness of education investments and research investments, particularly given that the results of investments in both areas may not be evident for many years, especially if they are potentially transformative and highly innovative.

3. **Your request includes a significant increase in Graduate Research Fellowships, with a goal of tripling the number of new awards by 2013. You obviously think this program is critical to building the STEM workforce.**

What results has this program produced to explain why it is singled out for such a large increase?

Answer: The Graduate Research Fellowship program (GRF) is designed to ensure the vitality of the scientific and technological workforce in the U.S. and reinforce its diversity by recognizing and supporting the country's most promising graduate students in STEM disciplines. NSF Graduate Fellows are expected to become leading experts who can contribute significantly to research, teaching, and innovations in science and engineering. This program funds people, not projects, equipment or facilities. By providing support for graduate education to the most promising and capable U.S. citizens, nationals, and permanent residents, the supply of scientific and engineering talent in the United States is directly supported. A diverse talent pool of young Americans is attracted to science and engineering careers by the GRF. By increasing the number of awards, the country will get more top students, including a higher proportion of women and members of underrepresented groups, studying and earning doctorate and master's degrees in science and engineering. For fellows, the 2002 WestEd evaluation found that the value of the fellowship was related primarily to financial assistance and prestige, and that it increased the freedom of recipients to make important choices regarding research and teaching. The evaluation also found that Graduate Fellows have a higher Ph.D. completion rate than non-fellowship graduate students.

The GRF has supported the graduate education and research of a substantial number of the leading U.S. scientists and engineers: 230 National Academy Scientists, 126 National Academy Engineers, and 33 Nobel Laureates. Graduate Fellows include a significant number of key science staff in the U.S. government. For example, John Holdren, Director of the Office of Science and Technology Policy, and Lawrence Summers, Director of the National Economic Council, were Graduate Research Fellows. The WestEd evaluation found that having a GRF "is an asset in getting postdoctoral fellowships, securing research funding, and searching for a job."

Given the unique contributions as highlighted above, the increased resources will support the development of the Nation's future scientists and engineers. FY 2009 marked the beginning of a growth trajectory to triple the number of new awards made each year to 3,000 by 2013 as stipulated by the Administration. The National Opinion Research Center at the University of Chicago is currently conducting an independent evaluation of the GRF. Findings will be available in September 2011.

4. **Past studies have found that there was an urgent need to improve our science education at every level, and identified two critical challenges we faced: 1) coordinating and bringing coherence across Federal, State and local programs; and 2) increasing the supply of well-prepared STEM teachers. How well have we done in addressing those challenges over the last few years?**

   Answer: Although science (and STEM) learning at all levels in the U.S. needs continued improvement, there has been some progress evident in recent years. For example, in the National Assessment of Educational Progress, trend scores in mathematics at the fourth and eighth grade levels have shown gradual improvement, and black and hispanic students' gains over many years in the trend studies are greater than gains of white students. Efforts at coordination and coherence across Federal, State, and local programs have increased. For example, NSF's Math and Science Partnership program collaborates with the U.S. Department of Education's state-level MSP program by disseminating findings from the NSF-funded R&D efforts, and NSF meets regularly with colleagues at the Department of Education to determine ways to fully translate educational research into educational practice. Also, federal agencies are participating in the development of a number of electronic forums aimed at informing state and local educational practitioners and policymakers about resources developed through federal initiatives. Many states have P-20 STEM education councils, or business and education coalitions of various types. And, in mathematics, the Common Core State Standards Initiative, led by the Council of Chief State School Officers, may lead to increased curricular coherence.

   Efforts to increase the supply of well-prepared STEM teachers have focused both on the preparation of more, and stronger, STEM teachers through such programs as the Noyce Teacher Fellowships at NSF. NSF is also supporting the Association of Public and Land-grant Universities' *Science and Mathematics Teacher Imperative*, which seeks to dramatically increase the number and diversity of mathematics and science teachers in middle and high schools; NSF's funding enables the development of analytic tools and research to be conducted on this effort among higher education institutions that are the predominant source of new teachers across the Nation. Another key factor in ensuring a strong STEM teaching force is to emphasize retention of well qualified teachers. A number of NSF programs (e.g., MSP, DRK-12, CCE, etc.) develop models for extensive and coherent teacher professional development for STEM teachers.

Stimulus Programs

5. **The Stimulus bill provided $3 billion to the NSF in FY09, representing a one-time 50% increase in funding. What challenges did this one time infusion of funds create, and what are you doing to manage the awards process to ensure that funding rates remain stable as possible, and that funds are available for continuation of grants and for new grants?**

   Answer: Receipt of $3.0 billion from the American Recovery and Reinvestment Act in FY 2009 raised significant challenges in agency operations and award management, primarily stemming from the requirement that NSF administer the additional funds within its existing workforce and resource constraints (since no ARRA money was given for administrative functions).

   NSF continually assesses the tradeoffs among different investment strategies:
   - Increasing the percent of our portfolio allotted to research grants would maintain funding rates but place pressures on the funding of other NSF activities, such as learning and research infrastructure programs and internal operations.
   - Decreasing the average award size would maintain funding rates, but would create budgetary obstacles for fundees, which would ultimately inhibit discovery. For example, smaller award sizes in an environment of flat or increased costs would likely decrease the number of people an investigator would be able to support, which would slow discovery and train fewer students.

   NSF honors its commitments to continuing grants before calculating the percentage of its portfolio that can be devoted to new awards.

6. **As a result of the Stimulus funding, you made 14,605 competitive research awards in FY09. You are on a path to make more than 3,000 fewer in FY10. Most NSF research grants are typically three year grants. Are you facing a situation where the demand for new grants in FY12 will likely far outstrip available funds and as a result your funding rate will be greatly reduced?**

   Answer: Funding rate is a function of the number of proposals NSF receives. We cannot predict the demand for funding in FY 2012, but even if it is high, whether or not the demand will affect funding rate depends on NSF's investment strategy as described in answer to the previous question (see above response).

7. **The infusion of Stimulus funds raised your FY09 funding rate to 32%, the highest level in many years. What is your projected funding rate for FY10 and FY11, and what are the practical effects of that on researchers seeking funding?**

Answer: NSF's projected funding rate for FY 2010 is 23 percent, and the projected funding rate for FY 2011 is 24 percent. In the short term, lower funding rates mean that researchers spend more of their time identifying funding opportunities and writing and submitting proposals and less of their time conducting research and training. In the medium term, the low funding rates can lead to deferred opportunities for recent STEM graduates. Further, when funding is perceived as scarce, researchers propose more conservative projects, which may slow the pace of discovery in the long term.

8. **Can you bring us up to date on how much has been obligated and spent? Are you on track to fully obligate this funding by the end of FY10?**

Answer: As of March 31, 2010, $2.68 billion has been obligated, $225.58 million has been expended, and 4,889 grants, contracts, cooperative agreements, and fellowship actions have been processed against NSF's ARRA appropriation for the Research and Related Activities, Education and Human Resources, and Major Research Equipment and Facilities Construction accounts.
NSF obligated 89 percent of its ARRA funding by March 31, 2010 and anticipates that all ARRA funds will be obligated by September 30, 2010. Examples of outstanding activities include:

- All Major Research Instrumentation (MRI) except one requiring an environmental impact assessment, and Science Masters Program awards, expected to be made in June, 2010. The final MRI award will be made by September 2010.
- EPSCoR awards, expected to be completed by June, 2010
- Academic Research Investment (ARI) awards, expected to be completed by September, 2010

Doubling Path

9. **The American Competitiveness Initiative, begun under the last administration proposed for NSF, along with NIST and DOE-Science, a ten year doubling path beginning in FY07. This was endorsed by Congress and the current administration in the form of the America COMPETES Act. Does this budget continue the doubling of the NSF budget by FY 2016?**

   Answer: The FY 2011 Budget Request sustains the President's commitment to double, by FY 2017, the budgets of three key science agencies, including NSF.

Major Research Equipment and Facilities Construction

10. **Your request for the Major Research Equipment and Facilities Construction account includes initial funding for NEON, the National Ecological Observatory Network. The initial funding requested for FY11 is $23 million. What is the total project cost, and why is this project important?**

    Answer: The not-to-exceed total project cost for NEON is $433,789,932.

    The National Ecological Observatory Network (NEON) is important because no other standalone system – federal or private, national or international – can provide the scientifically validated suite of data measurements or research capabilities that NEON will provide. The NEON mission is to enable understanding and forecasting of the impacts of climate change, land use change and invasive species on continental-scale ecology by providing novel infrastructure to support research, education and environmental management in these areas. The Observatory's network of coordinated sensors, experiments, and cyberinfrastructure will collect the ecological data needed to develop the scientific understanding and theory necessary to address the Nation's grand ecological challenges.

    NEON is designed to understand and predict: (1) how ecosystems work and respond to changes, especially at large scales; (2) how ecosystem processes feed back to alter earth system processes, including climate and hydrology; and (3) the implications of these processes and feedbacks for human endeavors. NEON will provide systematic, long-term, large-scale data sets and a research and education platform for investigator-initiated sensors, observations, and experiments. NEON's facilities are designed to provide integrated, co-located measurements and infrastructure to support additional PI studies of ecological cause and effect. NEON will measure key aspects of the drivers and selected indicators of the responses (the full range of possible response variables is nearly infinite) while providing infrastructure for additional sensors, observations, experiments and learning opportunities.

NEON must achieve this with continental reach and over decades, preserving the data with integrity and accessibility over these time and space scales. Included as part of the infrastructure are several key science and education facilities:

- The Fundamental Sentinel Unit (FSU) measures key response variables in selected taxa (plants, insects, birds, small mammals, pathogens, phytoplankton, fish, and microbes) and media (soil and water). The measurements are made in the field and analyzed in the laboratory.
- The Fundamental Instrument Unit (FIU) measures climate (temperature, incoming solar radiation, humidity, wind velocity, precipitation), and climate-related physical variables (soil temperature, water chemistry, streamflow, and stream temperature). The FIU also measures some biological responses (soil carbon dioxide flux, photosynthesis and transpiration, leaf area). FIU measurements are made with in situ sensors.
- The Airborne Observation Platform (AOP) observes land use drivers, plant canopy, and habitat structure characteristics in the region around NEON sites, using remote sensing instruments deployed on a light aircraft. The AOPs would include three aircraft equipped with remote sensing instruments that would provide regional information for scaling and extrapolation. Each domain would be flown once per year during the growing season (typically April through October). The AOP will be composed of a novel imaging spectrometer, small footprint waveform-LiDAR, an airborne digital camera, and a dedicated Global Positioning System (GPS) and Inertial Measurement Unit.
- The Land Use Analysis Package (LUAP) provides information on land use and land management drivers at a continental scale as well as information on land use not accessible through remote sensing (e.g., fertilizer inputs, cultivation intensity, and forest rotation length). The LUAP is a gateway to a wide variety of geospatial data products, including remote sensing and statistical data, and it also provides convenient and coordinated access to other context variables such as soils maps and climate observations and projections.
- A Mobile Deployment Platform enables a subset of the FSU and FIU measurements to be strategically deployed in response to abrupt events, PI-driven investigations, or educational opportunities.
- Stream Observation Network Experiment (STREON) seeks to study how stream ecosystems respond to an acceleration of two of the key drivers of their structure and function: nutrient loading and loss of top consumers. STREON will consist of long- term nutrient addition and top-level consumer manipulation experiments conducted in multiple streams at NEON core and relocatable sites distributed across climate gradients in the United States and representing the dominant stream hydrologic regimes present in North America.
- The Education and Outreach component of NEON includes a suite of products that will enable physical and virtual use of the facility by a variety of

audiences, including scientists, educators, students, the general public, and decision makers.

- Cyberinfrastructure (CI) would provide the hardware, software, and central management to collect, evaluate, and manage the NEON scientific data; monitor distributed sensors and overall NEON system health; conduct problem tracking/routing; and manage information associated with NEON assets. CI will collect NEON data from a variety of sources, process and manage data via an internal workflow system, and integrate the calibration data, system health information, and scientific algorithms needed to evaluate and produce higher-level data products. Data products will be delivered to a diverse group of end users via web portals. The NEON observations will be integrated into multi-level data products.

11. Can you describe the process that led to the prioritization and selection of this project? What is the role of the National Science Board in this process? What changes have been made in this process recently and are you confident that it is working in an efficient and effective manner?

Answer: MREFC-funded construction projects proceed through a progressive sequence of increasingly detailed development and assessment steps prior to approval for construction funding. This process is described in NSF's Large Facilities Manual (*http://www.nsf.gov/publications/pub_summ.jsp?ods_key=lfm*).

Briefly, it mandates that project proponents define:

- What science questions the proponents hope to answer;
- What infrastructure is needed to answer these questions;
- What risks are associated with the construction or acquisition of these tools;
- What project management, budget, and schedule are necessary so that, with high confidence, appropriated funds will result in the creation of the requested infrastructure?
- What are projected operating costs for the facility, if constructed?

Proponents are directed to initially provide NSF with a "top down" system level description of scope, budget, risk, and schedule in a Conceptual Design, followed by a "bottom up" description, based on the lowest levels of detail, in a Preliminary Design, and finally a "shovel ready" implementation plan in a Final Design. NSF conducts reviews and makes decisions on which projects advance at each of these design stages. The goal of this process is to bring forward for construction funding only those projects in which NSF has high confidence that the proposed scope can be completed within the proposed budget.

This process had not been implemented a decade ago when NEON was originally proposed for construction. With the organization of the Large Facilities Office, the Large Facilities Manual was implemented, and as part of the FY 2009 NSF Budget Request to Congress (ref, page MREFC-2) it was determined that no further MREFC funds would be requested for NEON until it had successfully completed this process, including Final Design Review, which it did in November 2009.

Prior to endorsing construction of NEON, the National Science Board (NSB) conducted its own internal assessment of the NEON construction proposal. NSB reviewed the project's development history, its current status, and construction objectives, and endorsed NSF's proposed plans for sustaining operation of the facility and exploiting its research capabilities once it is constructed. Furthermore, NSB and NSF jointly determined that NEON continues to satisfy the Foundation's prioritization ranking criteria: it is a top priority within the ecological community, it is projected to have a transformative impact on this and related fields of research, and it is projected to result in knowledge that is broadly important to the Nation. (Refer to Appendix 2 of the Large Facilities Manual for more detail).

There have been a few recent changes to the process within the last year. The Large Facilities Manual was revised in 2009 to: (1) clarify the role of the Deputy Director for Large Facility Projects, (2) add a requirement that, should there be an extended period between Preliminary and Final Design Reviews, NSF will conduct update reviews at least annually to assure itself that that the total project cost and basis of estimate, schedule, and risk management plan presented at the Preliminary Design are still valid, (3) make clear that a significant proportion of the budget at Final Design be based on externally provided cost information such as vendor estimates or quotes, publically available supplier prices, etc.; (4) include the NSB Resolution that recompetition of the operation of existing large facilities be regularly reconsidered; and (5) implement a "no cost overrun" policy that requires that the cost estimate contain adequate contingency to cover all foreseeable risks, and that any cost increases not covered by contingency be accommodated by reductions in scope.

NSF and NSB continue to regularly assess this process to ensure it reflects what has been learned from experience, and to position ourselves to address future challenges. For example, examination of how NSB might be involved at an earlier stage in the development process in selecting and prioritizing candidate MREFC projects, to make sure we have the right balance between infrastructure investments and direct research funding are currently taking place.

NSF is confident that the process implemented is sound. That confidence is based, in part, on the evidence within the review reports and corroborating inputs from NSF staff. For example, the NEON Final Design Review was comprehensive, utilizing 19 individuals able to provide expert judgments in each of the major technical or management areas needed to accomplish the project. This review included a separate subcommittee that focused exclusively on the budget estimate, drilling down in several areas of the budgetary planning to examine in detail the supporting cost details, basis of estimate, scheduling details, and risk assumptions. This assured us that NEON's methodology was sound.

A further reason for confidence in the process is that it has been demonstrated to be successful elsewhere. The process of progressive incremental investment in planning, followed by assessment at critical points, is widely used in government and industry. NSF's expectations for planning and risk management at the key decision points: the conclusion of Conceptual Design, Preliminary Design, and Final Design, are well understood by the research community and consistent with best practices for project management.

12. I understand that NEON had an earlier estimated total construction cost of $100 million. What changed, and is the program still justified given a greater than 300% cost growth?

Answer: The change in cost reflects a change in scope and design. From 1999 through 2009 NEON evolved through three design alternatives from a network of Regional Observatories to a network of Themed "Grand Challenge" Observatories to the Requirements-based Observatory design for a continental-scale, integrated system – the NEON of today. NEON was initially proposed as 17 regional, instrumented, ecological observatories connected via a cyber backbone into a network to expand site-based research to address the questions identified in the NRC report, *Grand Challenges in Environmental Science* (2001), in a larger, more integrated regional context. This regional NEON design was included with a construction cost of $100 million in the original MREFC budget request. In 2003 the National Research Council (NRC) evaluated the NEON's proposed regional design and scientific scope. The 2004 NRC report (*NEON: Addressing the Nation's Environmental Challenges*) recommended a change in design from regional observatories to multiple "grand challenge" themed continental observatories to make it better suited for regional to continental scale ecological research. In FY 2006, a NEON design committee convened 200 scientific, engineering, and education professionals to develop the science and technical requirements and the NEON Conceptual design. The requirements-based observatory design was optimized to concurrently address the NRC "six Grand Challenge themes", had a statistically derived continental design, combined standardized in-situ and remote sensing measurements, and included experimental infrastructure. The schedule and costs were re-evaluated consistent with the revised scope.

The current NEON design was scientifically optimized to provide an integrated and standardized network of research infrastructure that will enable regional to continental scale ecological research. The design scope, schedule, and cost have been extensively reviewed as prescribed by the NSF and the NSB and as outlined in the Guide for Large Facilities and including advice and assistance of the Large Facility Office Deputy Director. The conceptual design, preliminary design, and final design phases were reviewed by panels of experts selected by NSF. The final design review concluded that the scope, schedule, and costs were credibly defined in a disciplined manner, accounted for all cost elements, was based on reasonable assumptions and reasonable forecasts of market conditions and was adequate to complete the NEON Project.

13. I understand that you are planning to conduct an additional baseline review of NEON in early FY11 prior to the initiation of construction, should Congress provide the funding. Are you expecting that review to result in additional cost growth?

Answer: No, NSF is not expecting the review to result in additional cost growth. NSF has a no cost overrun policy which requires a cost estimate have adequate contingency to cover foreseeable risks. NEON, Inc. rigorously identified known risks across all aspects of the project and defined risk-based contingency to address those risks. The NEON Project total project cost contains adequate contingency to account for the known risks that might result in cost growth. Should a previously unknown risk be identified during baseline review that cannot be accommodated by the current project contingency, NEON, Inc. will be instructed to de-scope the project to ensure construction of the observatory within the submitted budget. The NEON Project has carefully defined and reviewed de-scope options should such a situation arise.

Representative Robert B. Aderholt
Questions for the Record

1. **A well-educated population, especially in the fields covered by STEM programs, is needed to ensure that the United States remains competitive globally. Fewer women are in STEM education than men. What is the NSF doing to encourage women to go into these fields?**

   Answer: NSF supports efforts to encourage girls and women to choose STEM education and careers in every directorate across the Foundation. In 2008, NSF sponsored an internal working group on Broadening Participation whose charge was to catalogue the efforts on-going throughout the Foundation to support individuals, organizations, and regions of the country currently underrepresented in the NSF portfolio of awards or participating in NSF-sponsored projects, including women and girls. The report from the working group, "Broadening Participation at the National Science Foundation: A Framework for Action," is available at http://www.nsf.gov/od/broadeningparticipation/nsf_frameworkforaction_0808.pdf. The report details programs across the Foundation that encourage women and girls to choose STEM fields. Two principal programs addressing the underrepresentation of women in STEM are the Research on Gender in Science and Engineering (GSE) program and the ADVANCE: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers (ADVANCE) program. These are detailed below:

   The GSE program supports research to understand and address gender-based differences in education and workforce participation among girls and boys, women and men, from kindergarten through the undergraduate years. In addition to research, the GSE program also provides a mechanism for engaging a wider audience of practitioners with research findings and strategies for changing educational practice relative to gender issues. Furthermore, the GSE program has been funding the objective to increase girls' and women's interest in STEM education and careers since 1993.

   The specific goal of the ADVANCE program is to increase the representation and advancement of women in academic science and engineering careers. Specifically, ADVANCE encourages institutions of higher education and the broader STEM community to address various aspects of STEM academic culture and institutional structure that may differentially affect women faculty and academic administrators. To date, the NSF has invested over $103 million in various types of ADVANCE projects.

2. **Given the increased level of research and development funding worldwide, especially in China, how should the United States move forward in the long term to maintain its global competitiveness? In what areas do you see the most potential for improvement within the US?**

Answer: Increased R&D funding worldwide is often combined with strategies to expand and deepen availability of and access to higher education. Both are aimed at developing countries' S&T capabilities and spurring indigenous innovation capacity. These developments are likely to persist, and perhaps even accelerate, and they offer both opportunities and challenges to the U.S. leadership position in S&T. Opportunities arise from the possibility of enhanced fruitful scientific collaborations, sharing of new ideas and insights, and a quickened pace of discovery. The challenges revolve around how to keep the United States nimble and flexible so it can take advantage of these developments and produce value for our citizens.

The United States cannot afford to stand aside from these developments, but has to seek full engagement with the broadest possible range of the world's S&T centers. It should incentivize the assimilation of the best innovative ideas, practices, and products, no matter where developed, and build upon them. The United States should also protect and nourish its higher education system, which combines world-best basic research and graduate training and is a source of path-breaking innovative ideas. The United States should also take full advantage of its continuing attractiveness to foreign talent and welcome the world's best and brightest to come and contribute to America's strength. They would enrich the internal U.S. innovation capacity, provide a conduit for international collaboration, and be a source of information about promising developments elsewhere. And finally, the United States must find a way to break out of its weak international position in K-12 education performance. Both the Administration's education initiatives and the governors' initiative to develop broad common curricular guidelines are aiming at that critically important goal.

WITNESSES

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