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HUMAN SPACEFLIGHT: THE SPACE SHUTTLE AND BEYOND

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

MAY 18, 2005

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ONE HUNDRED NINTH CONGRESS

FIRST SESSION

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HUMAN SPACEFLIGHT: THE SPACE SHUTTLE AND BEYOND

WEDNESDAY, MAY 18, 2005

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 10:47 a.m. in room SR–253, Russell Senate Office Building, Hon. Kay Bailey Hutchison, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Senator HUTCHISON. I am starting because there is a possibility that at 11:30 we will have to break because of what we call the 2-hour rule being invoked. And therefore, I am going to jump right in with our first witness and want to welcome Dr. Griffin. We very much appreciate all that you have done in the very short time that you have been in place. Today's focus is going to be the Space Shuttle and how we are going to utilize it fully and go forward with a crew return vehicle. We are very concerned on this Committee, as we have made clear, and I know you are as well, about the current status of our ability to fly the Space Shuttle beyond Return to Flight, how long can we use it, and what your plans are to bring up the crew return vehicle.

In addition, in the question period I want to say that I want to start talking about not only the crew return vehicle, which is, I know, in the top three priorities for NASA, but what we are planning to do with cargo, a capacity to take the payloads to and from space that we cannot take on the crew return vehicle.

You have said to me straight out the Space Shuttle is flawed. The words are indelibly impressed on my mind from the last hearing. And therefore, I want to know how we are going to get equipment and repair-type tools up there, when we have a crew return vehicle, and where that stands in the priority list.

It is essential that we learn from mistakes made in the past, as we develop a new generation of vehicles for human space flight. We do not have the luxury of time or resources or making a false start, as we add the new dimension of Moon, Mars, and beyond. So I hope that we can go one step beyond where you did in your hearing for confirmation about where you see the main priorities for NASA, which are Return to Flight, the Crew Return Vehicle, and the finishing of the Space Station.

And, of course, as you know, Dr. Griffin, my fourth priority, but very high on the list and considered essential to me, is the science research at the Space Station going on a continuing basis rather than being delayed for the first three priorities.

So with that, I will welcome my Ranking Member, Senator Nelson, who is our only senator who has been in space. And let me say I am glad you are here.

[The prepared statement of Senator Hutchison follows:]

PREPARED STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

I am pleased to welcome our witnesses here today for this hearing on Human Space Flight—The Space Shuttle and Beyond. I know you are all very busy people, and the Subcommittee appreciates your willingness to be here with us to discuss some very important issues for the future of human space flight.

I am especially pleased to welcome Dr. Michael Griffin here, who is perhaps busier than all of us, as he continues to assume the helm of NASA, assemble his leadership team, and prepare to give the go-ahead for the Space Shuttle's return to flight.

We begin the focus of today's hearing on the Space Shuttle, because that is this nation's only human space flight vehicle. The Space Shuttle continues to represent an incredibly valuable national asset. We all share, I'm sure, the great hope that it will return to flight in July as a safer, more capable vehicle than ever before.

This hearing is not intended to delve into the near-term issues or the steps taken to prepare for Return to Flight. Rather, we hope to review the role of the Space Shuttle as representing an essential U.S. capability to fly humans and cargo into space and back to the Earth. We will hear about the current status of our ability to continue flying the Space Shuttle, and plans for its use after a successful Return to Flight. We expect to hear about the need to ensure that the United States has such a capability and can sustain human space flight into the future without a serious gap in our ability to do so. We hope to hear what steps are now being taken and will be taken in the future to develop a successor to the Space Shuttle in a manner that provides a smooth, uninterrupted transition from one U.S. human space flight capability to the next.

With talk—and plans—to retire the Space Shuttle, we must carefully guard against the premature loss of either skilled expertise in the workforce or industrial capacity to support and sustain the Space Shuttle for however much longer it will fly. Members of our second panel will address these and other issues.

It is essential that we learn from the mistakes made in past efforts to develop a new generation of vehicles for U.S. human spaceflight. We do not have the luxury of either time or resources to make another false start as we add the new dimension of the Moon, Mars and beyond to this nation's human spaceflight capability.

This hearing is intended to set the stage for what will be the Subcommittee's ongoing efforts to monitor and ensure the success of U.S. efforts to sustain an effective, uninterrupted national human spaceflight capability.

I look forward to our witnesses' testimony and their response to questions of the Subcommittee.

STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Thank you, Madame Chairman. And I understand that it is possible that we are going to have to conclude this by 11:30. Is that correct?

Senator HUTCHISON. That is correct.

Senator NELSON. OK. Then I will just say, Dr. Griffin, in the interest of time, I think you have demonstrated extraordinary leadership. And you have only been on the job a month. But, of course, we knew that. That is why Senator Hutchison and I both encouraged your appointment and then your confirmation, once appointed. So we are very grateful. And I think that what you have done in trying to lessen the hiatus between the CEV and the end of the Space Shuttle is not only commendable, it is absolutely necessary, as well as you taking a fresh look at whether or not we can go and service Hubble. I thank you for that.

And I will reserve my comments for questions.

Senator HUTCHISON. Thank you, Senator Nelson.

Senator Lott?

STATEMENT OF HON. TRENT LOTT, U.S. SENATOR FROM MISSISSIPPI

Senator LOTT. Thank you, Senator Hutchison. And I am so pleased that you have taken over this Subcommittee Chairmanship. Your interest, your knowledge, and your energy will be very helpful.

And I want to also recognize Dr. Griffin's good work already. I just sense a change already, which is pretty impressive. And I am wishing you the best. And we want to be partners with you in trying to get this very important agency up and running and doing the kind of job we know it can do.

I know there will be lots of discussion about your plans to accelerate the Crew Exploration Vehicle acquisition and how NASA's other programs will be affected by the increased emphasis on space exploration. I look forward to working with you to achieve the former while making the latter more plausible.

I also want to thank you for going forward with the NASA Shared Services Center decision. I think you made a good choice. Obviously I am prejudiced in that regard, but there were a lot of things to consider, a lot of countervailing pressures. And I think you made the right decision and that the history of this will show that it will serve NASA well.

I also understand that the U.S. Trade Representative is providing you with guidance on the use of NASA facilities in connection with a EADS-proposed U.S. commercial aviation research and manufacturing facility. And I would urge you to work as closely as you can with the State of Mississippi and Hancock County in our state with respect to this proposal.

And so basically, I just wanted to get those things on record. And at this point it makes me feel good to be able to come to a NASA hearing and commend a NASA representative for their effort. Maybe it is just because you are just getting started, but I hope you can keep it up. Good luck, sir.

Senator HUTCHISON. Thank you, Senator Lott. I am very pleased that you are staying active on the Subcommittee, because I do want to have a reauthorization of NASA this year. And I do plan to invigorate our oversight efforts.

Dr. Griffin, welcome.

STATEMENT OF DR. MICHAEL D. GRIFFIN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. GRIFFIN. Thank you, Senator Hutchison, Senator Lott, Senator Nelson. I appreciate your very kind remarks.

I will endeavor to continue in the pattern that we have begun in our relationship, which is to give you the best answers that I have to the questions that you ask. And if the answers are difficult, then

I look forward to working with you to make them as palatable as we can. But I will tell you every time what I believe to be the case.

Senator Hutchison, while you were mentioning that the most important person for the hearing was here so we could start, I was actually thinking in my own mind that my role was more like that of the pig in a ham and eggs breakfast. You cannot start without me, but I am at the wrong end of the food chain.

[Laughter.]

Dr. GRIFFIN. So with that, I will continue with my formal remarks.

Madam Chair and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the plans for the Space Shuttle in carrying out the first steps of the Vision for Space Exploration with Return to Flight and assembly of the International Space Station, our plans to date for the Shuttle retirement by 2010, and our progress in minimizing the gap between retirement of the Orbiter and the first flight of the Crew Exploration Vehicle.

In presenting the vision last year, the President——

Senator HUTCHISON. Dr. Griffin, could I interrupt you?

Dr. GRIFFIN. Yes, ma'am.

Senator HUTCHISON. You were not planning to read your whole statement, were you? Could you summarize?

Dr. GRIFFIN. I had an oral statement.

Senator HUTCHISON. Is it different from your written statement?

Dr. GRIFFIN. It is. But let me shortcut it in the interest of time. Let me just go forward and say we are in the middle of returning to flight. As you know, we delayed by 3 months. We think that was the right thing to do. The recommendation was presented to me, and I concurred with it. We are still working some technical issues. We will go when we can.

We are, as I believe you now know, working vigorously at NASA to consider alternate options for space station assembly sequence, looking at how we can complete the station consistent with our obligations and yet consistent with a Shuttle retirement date in 2010. I have promised the Congress the results of this internal study by mid-summer.

We are looking at phasing out Shuttle operations. We have studied lessons from the Titan IV community. We are considering how the phase-out of the Shuttle orbiter will be consistent with the development of a new architecture for the CEV, its transportation system and human return to the Moon. There are a number of critical decisions that need to be made in that regard. And we will be sharing those with you as we go forward.

As I have just said, we have an Exploration Systems Architecture Study (ESAS) ongoing at headquarters in parallel with our Space Station assembly study. Preliminary results from that study also will be made available to the Congress by mid-summer. And I look forward to working with you as we shape that up.

And with that, as I have testified previously in my confirmation hearing and last week, I believe with you that the gap in human space flight capability, access to space by the United States between the necessary retirement of the Shuttle Orbiter and the bringing on line the new Crew Exploration Vehicle must be absolutely minimized. And I look forward to working with your Committee and with the Congress as a whole to achieve that goal.

Thank you. And I stand ready for your questions.

Senator HUTCHISON. Well, thank you.

[The prepared statement of Dr. Griffin follows:]

PREPARED STATEMENT OF DR. MICHAEL D. GRIFFIN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Madam Chair and Members of the Subcommittee; thank you for the opportunity to appear before you today to discuss the status and role of the Space Shuttle in human space flight, our plans for the Shuttle's retirement, our progress in minimizing the gap between the retirement of the Space Shuttle and the introduction of the Crew Exploration Vehicle.

On January 14, 2004, President George W. Bush announced the *Vision for Space Exploration*. The President's directive gave NASA a new and historic focus and clear objectives. The fundamental goal of this directive for the Nation's space exploration program is ". . . to advance U.S. scientific, security, and economic interests through a robust space exploration program." In issuing this directive, the President committed the Nation to a journey of exploring the solar system and beyond, returning humans to the Moon, and sending robots and ultimately humans to Mars and other destinations. NASA embraced this direction and began a long-term transformation to enable us to achieve this goal.

The first steps in enabling the *Vision for Space Exploration* are to return the Space Shuttle fleet to flight, to focus the use of the Space Shuttle on completing assembly of the International Space Station, to retire the Space Shuttle by 2010, and to replace it as soon as possible thereafter with the new Crew Exploration Vehicle (CEV). Given the importance of ensuring that the Space Shuttle is returned to flight safely, the Space Shuttle program and, indeed, the whole of NASA has been devoting its available resources and human capital to ensuring that this first step is executed to the best of our abilities. Once the two Return to Flight missions are behind us and we have developed a higher level of confidence in the knowledge of the Shuttle debris environment, we can focus a greater level of attention on the important issues surrounding Space Shuttle transition and the development of the next generation of human spaceflight vehicles.

Space Shuttle Return to Flight

On April 28, 2005, the Space Shuttle program management recommended that we extend our planning for the first Return to Flight mission, STS–114, to support the launch window that opens in July 2005. I concurred with this recommendation. This change was not the result of any single problem, but instead reflected the need to take additional time to perform our verification and validation reviews, and to assess the results from the External Tank (ET) fueling test performed on April 14, 2005. We knew that there were some open questions going into these reviews and tests, and we had very detailed plans for developing answers to those questions. We also understood that the reviews and tests might raise additional questions before Return to Flight, and that we would have to be prepared to review our plans and launch opportunities in light of this. That is exactly what happened. One of the most notable outcomes was our decision to modify the feed line bellows area with an electrically powered heater to further reduce or eliminate the ice that naturally forms in the area.

This decision to insert some additional planning time to support a mid-July launch opportunity was not made lightly. Everyone in the Space Shuttle program recognizes that we have an extremely important mission to carry out, and that completing assembly of the International Space Station and executing the *Vision for Space Exploration* cannot happen until we return the Space Shuttle to flight. At the same time, this change reflects our continuing commitment to remain focused on safety of flight considerations and prudent engineering decisions. Transporting people into space remains risky compared to most other human endeavors. We must make sure that every decision to send people on missions into space is made with the utmost concern for their safety.

Today, work continues in preparation for another ET tanking test scheduled for as early as tomorrow, May 19, while the STS–114 Shuttle stack is still at its launch pad. Engineers and technicians are adding instrumentation to the tank to help troubleshoot two problems that were detected during its first tanking test on April 14. The instrumentation will provide data to further analyze and diagnose the cause for these two problems: the liquid hydrogen sensors that gave intermittent readings and the liquid hydrogen pressurization relief valve that cycled more times than standard during last month's test. Following the tanking test, technicians will prepare for rolling back Discovery to the Vehicle Assembly Building (VAB) no earlier than May 24. In the VAB, Discovery will be removed from its ET and lowered into the transfer aisle.

It has taken an extraordinary effort to return the Space Shuttle fleet to flight readiness status. One hundred and sixteen individual hardware modifications (41 of which were directly related to the 15 Return to Flight recommendations of the *Columbia* Accident Investigation Board [CAIB]) and over 3.5 million work-hours have gone into Return to Flight, raising the bar, and launch processing activities on Space Shuttle *Discovery* alone. Our Return to Flight effort has been focused on identifying hazards, re-designing current systems to eliminate or control those hazards, providing means for warning that hazards might have occurred during flight, and emplacing standardized special procedures to counter any hazardous conditions that might arise. We have eliminated the External Tank bipod foam which was the proximate cause of the Space Shuttle *Columbia* accident on February 1, 2003. The crews on board *Discovery* and the International Space Station will now be able to detect critical damage to the Space Shuttle's thermal protection system during the first two development test flights and, in the unexpected event of severe damage, to take shelter in the International Space Station until a rescue mission can be launched. We have gone well beyond the recommendations of the CAIB to reduce risks and provide additional safety measures through added hardware improvements and procedural changes.

Return to Flight has been a massive effort, focusing the energies of every technical discipline across all the NASA Centers and Space Shuttle contractors on a very specific objective. It has been, in short, an example of NASA at its finest. I am very proud of this Space Shuttle team and this Agency for their hard work, their diligence, and their incomparable expertise and professionalism during these difficult times.

But returning the Space Shuttle fleet to flight status is only the first step in the Nation's *Vision for Space Exploration*. Over the next few years, the Space Shuttle fleet will resume executing some of the most complex missions ever attempted in space. The return to Space Shuttle operations means that NASA can once again return to assembly of the International Space Station. The first two Space Shuttle Return to Flight missions, STS–114 and STS–121, are development test and logistics missions which will focus on carrying cargo to the Station and thoroughly exercising the extensive hardware and process changes made during the past 27 months. Following those two flights, the crew of STS–115 will resume the assembly of the International Space Station. We will complete assembly of the International Space Station using the minimum number of Space Shuttle flights necessary.

Space Shuttle Transition—Scope

As the Space Shuttle resumes its mission, NASA will begin tackling an equally challenging assignment—ensuring a safe and orderly retirement of the Space Shuttle system by 2010 and a graceful transition of the Space Shuttle knowledge, workforce, and assets to future exploration missions. We need to maintain a robust program that is capable of safely executing the remaining Space Shuttle missions while, at the same time, not displacing the orderly pursuit of necessary transition activities.

This effort could very well be one of the largest single planned transitions NASA (or any federal agency) has ever undertaken. The Space Shuttle program occupies 640 facilities, utilizes over 900,000 equipment line items, and directly employs over 2,000 civil servants and more than 15,000 work-year-equivalent prime contractors, with an additional 3,000 people working indirectly on Space Shuttle activities at all NASA Centers. Thousands more are employed at the subcontractor level in 43 states across the country. The total equipment value held by the Program is over $12 billion. The total facilities value held by the Program is approximately $5.7 billion (approximately one-third of the value of NASA's entire facility inventory), mostly at the field centers. There are also approximately 1,500 active suppliers and 3,000–4,000 qualified suppliers that directly support the Space Shuttle program.

Of all these assets, the most important are, of course, the people. Space Shuttle transition will have an unavoidable impact on NASA's workforce. The early transition of workforce elements, the need to retain segments of that workforce, and the transition of program knowledge to future programs must all be addressed. We will ensure that this transition treats these dedicated people with the respect they deserve, and that their knowledge and experience will be captured or converted as we begin the next phase of exploration. There will be challenges, but we will ensure that critical skills are retained for safe mission execution through the operational life of the program.

NASA and the Space Shuttle program will also face significant challenges in terms of balancing different technical and programmatic requirements: (1) maintaining access to the necessary equipment, facilities, and vendors needed through Space Shuttle flyout; (2) identifying and maintaining those capabilities that may be needed for next-generation exploration systems activities, and; (3) retiring unneeded capabilities to free resources that will support future exploration. For example, because the amount of flight hardware accumulated (including spares) will be sufficient to meet the current mission manifest through 2010, several key Space Shuttle hardware vendors and sub-tier suppliers will be ending their relationship with the program prior to 2010. Draw-down decisions need to be made with regard to equipment and facilities which currently support (and are supported by) the Space Shuttle program. These resources will need to be characterized and dispositioned in such a way that either supports exploration goals or removes them from NASA's books.

Many of these decisions depend upon the role that Space Shuttle knowledge, workforce, hardware, and infrastructure will play in follow-on launch vehicles. NASA is continuing to analyze next-generation crew and heavy-lift launch requirements in support of the *Vision for Space Exploration*, including the degree to which those requirements could be met by boosters derived from existing Space Shuttle propulsion components and systems. Flight-proven Space Shuttle propulsion elements (including the Space Shuttle Main Engines, the Solid Rocket Boosters, and the External Tank, as well as some of the existing Space Shuttle infrastructure and workforce) will be carefully evaluated, as their use may enable more rapid development of crew and heavy lift capability than other alternatives like Evolved Expendable Launch Vehicles (Delta IV and Atlas V). A decision to use Space Shuttle propulsion elements as part of our next-generation space transportation architecture would have a significant impact on Space Shuttle transition planning. However, since these launch vehicle requirements are not yet fully defined, current Space Shuttle transition planning must take into account the risks of prematurely terminating Space Shuttle vendors and retiring equipment and facilities that could possibly be needed to fulfill these requirements.

Space Shuttle transition will also be affected by the number and pacing of flights needed to complete assembly of the International Space Station. NASA is also currently examining alternative configurations for the Space Station that meet the goals of the *Vision* and the needs of our international partners, while requiring as few Shuttle flights as possible to complete assembly. This effort will be a factor in the formulation of NASA's FY 2007 budget, and we will keep Congressional Committees informed as the study effort progresses.

I believe that Space Shuttle transition will be one of the largest, most complex, and most emotionally-charged tasks facing NASA during the initial phases of the *Vision*. It cannot be started too soon.

Space Shuttle Transition—Processes

The single most important requirement in Space Shuttle transition is to maintain the highest level of flight and ground safety through the life of the Program. *The last flight of the Space Shuttle must be just as safe as the upcoming Return to Flight missions.* The success of Space Shuttle transition will also depend upon serving the goals of the *Vision for Space Exploration* in such a way that takes maximum advantage of existing programs and personnel, minimizes the negative impacts of transition on Space Shuttle team morale and performance, and ensures full compliance with all relevant federal, state, and local laws and standards.

Our transition planning began soon after the release of the *Vision for Space Exploration* a year ago. While our efforts over the past 2 years have been dedicated to Return to Flight, NASA has also concluded the exploratory phase of its Space Shuttle transition activities and has begun to set out the next steps in transition planning. We have benchmarked phaseouts in other high-technology, systems-intense programs, including the ongoing retirement of the Titan IV program, which just had its final launch out of Cape Canaveral on April 29, 2005. The Space Shuttle program has also asked the National Academy of Public Administration (NAPA) to assist us in our transition activities, particularly in the development of strategies and plans for the transition from the Space Shuttle program to the programs that will implement the *Vision for Space Exploration*.

Through the recent Integrated Space Operations Summit this past March, NASA engaged a broad community on a number of issues affecting both the Space Shuttle and International Space Station programs. For this past year's annual Summit, NASA chartered one panel specifically to study Space Shuttle transition. That panel considered several programs, including the Titan IV, and developed recommendations intended to lay the foundation for managing Space Shuttle transition activities. In accordance with these recommendations, the Space Operations Mission Directorate will establish the position of Space Transportation System Transition Manager. The initial efforts of this manager will be to develop the planning as recommended by the Transition Panel and to look for candidate areas for transition from the Space Shuttle program. We will select an individual to fill this position shortly.

The Space Shuttle program recognizes the importance of maintaining an experienced workforce to safely execute the Space Shuttle's mission through the end of the decade. The NASA Workforce Flexibility Act of 2004 provides the Agency with vital tools, such as the authority to provide workforce retention bonuses in critical skill areas, that will help retain the necessary human capital needed during mission execution. NASA has nine panels and teams looking at workforce issues across the Agency, in addition to the Integrated Space Operations Summit Transition Panel's workforce assessment. We have also invited human capital experts from government and private industry to advise us on best practices during Space Shuttle program phaseout.

Many of our contractor partners have begun taking steps (such as defining critical skill requirements and bringing in human capital consulting firms) to counter the impact of transition on mission execution. Provisions in the follow-on to the Space Flight Operations Contract (which runs through September 2006) will require the prime Space Shuttle operations contractor, United Space Alliance, to prepare for sustaining its required workforce, including submitting a critical skills retention plan.

Accelerating the Crew Exploration Vehicle

A cornerstone of the *Vision for Space Exploration* is a Crew Exploration Vehicle (CEV) and its associated launch system. The CEV will be developed in the latter part of this decade and deployed operationally as soon as possible. The primary mission of the CEV will be the exploration of the Moon and other destinations, but initially it will conduct missions in Earth orbit, including missions to the International Space Station.

Our earlier plans called for operational deployment of the CEV not later than 2014. As I testified during my confirmation hearing, I believe that the CEV development must be accelerated in order to minimize the gap between the 2010 Space Shuttle retirement and the first operational flight of the CEV. NASA has embarked upon a rigorous review of the Crew Exploration Vehicle (CEV) architecture to determine opportunities to accelerate the availability of the CEV. This assessment is a part of the "Exploration Systems Architecture Study" (ESAS), which I chartered on April 29, 2005. The product of this analysis is anticipated by mid-July 2005. Acceleration of the CEV program will be facilitated by down-selecting to a single contractor sooner than originally planned, and by deferring other elements of the exploration systems research and technology plan, like demonstration of nuclear electric propulsion, not required for the CEV or for the early phases of human return to the Moon.

The CEV will conduct missions in Earth orbit, including missions to the ISS, but its primary mission will be to support exploration of the Moon and other destinations. In addition, NASA's Exploration Systems Mission Directorate will be responsible for developing and acquiring crew and cargo services to support the International Space Station, and funds have been transferred to that Directorate, as reflected in the May update to the FY 2005 Operating Plan.

NASA needs to communicate our view of the CEV launch architecture and our requirements, and we will keep Congressional Committees informed as the ESAS study effort progresses. Going forward, the Agency will need a launch system for the CEV, one which does not at present exist. Two obvious possibilities exist by which we might obtain such a vehicle. The first is to develop a launch system derived from Shuttle components, specifically the SRB with a new upper stage. The second option is to upgrade the proposed heavy-lift versions of EELV, again in all likelihood with a new upper stage. As NASA Administrator, I must be a responsible steward of our funds, and a key aspect of the Agency's analysis of alternatives will be to capitalize on existing technical and workforce assets in a cost-effective and efficient way. NASA's goal is to develop a CEV capable of operating safely soon after the retirement of the Space Shuttle.

Summary

Space Shuttle transition represents an enormous challenge for NASA and for the Nation as a whole. While we have benchmarked other programs that are similar in scope to the Space Shuttle, the Shuttle is one of the largest single programs for which an orderly transition to disposal has ever been required. I do not want, and we should not want, to repeat the mistakes made in the aftermath of the Apollo program, where many unique capabilities were shut down abruptly and irretrievably. We must transition the Space Shuttle in a way that ensures continued safety in our ongoing operations, maximizes the efficiency with which we utilize our resources, respects the Space Shuttle workforce, and protects critical national capabilities that will be needed to support the *Vision for Space Exploration*. There will be hard decisions to be made over the next 5 years. It is vital, however, that we remain focused on the worthy and ambitious goals laid out by the President on January 14, 2004.

Thank you for the opportunity to testify today, and I look forward to responding to any questions you may have.

Senator HUTCHISON. I am so sorry we are having to do this quickly, because there is so much that we have to say and we have a great second panel, as well.

But let me ask you first, if I were to ask you what are the top priorities for the use of the Space Station, the research that you would do at the Space Station right now, what would those three priorities be?

Dr. GRIFFIN. The Space Station is very useful as a test bed for hardware that we will be developing for exploration. Much of that hardware that we intend to take to the Moon and later on to other destinations would be better flight tested in lower orbit close to home. One does not require that such hardware be tested on a space station, but given that we have one, that would be the logical place to do it.

There will be, as the years evolve, there will be a number of scientific experiments that can be palatized and can be attached to the Space Station, as opposed to necessarily being on a free-flying spacecraft. Again, if we did not have a Space Station, we might do otherwise. But having one, we will look for opportunities to use it.

There will be research that can be conducted on the station by the virtue of the ability of the station to provide an extended zero gravity time. Response of human and other organisms to zero gravity can be examined under controlled conditions on the station.

The station is limited in its research potential by the fact that we are not able on the station to combine the appropriate radiation spectrum for deep space flight together with the zero G environment.

It is those two environments together that are the truly relevant environment. And we cannot mimic those. But we can at least mimic the zero G portion.

Senator HUTCHISON. There is a consortium of universities now that takes the medical research that can benefit from being performed in space and that decides what the priorities are and then expands on those. Do you foresee within your budget being able to continue that consortium doing the medical side of the research that is going on at the Space Station?

Dr. GRIFFIN. Given the priorities that I have stated, that the Administration has supported, and that I believe are shared by this Committee, the short answer to your question is not in full scope. In order of priorities, I need to complete the return of the Space Shuttle to flight and fly every flight safely.

We need to complete the assembly of the International Space Station. Deferring it will likely only cost more money. We need, very much need, as you have said, to bring the CEV on line sooner rather than later, minimizing the gap in human space flight.

One of the few areas of freedom that I have as the administrator is the, I hesitate to call it a pot, but the pot of research and technology money that can be, if you will, bought by the yard. That is one of the few areas where I have any flexibility at all. If I am to accelerate the development of the CEV, a good chunk of that money must be used to do so.

Senator HUTCHISON. Would you provide for me and the Committee a cost estimate of what the biological research, the medical research, is, even if it is scaled back perhaps? But what about the ongoing experiments that we have heard about on breast cancer tissue? I would imagine that even in your top priorities, the zero gravity conditions still allow you to look at the osteoporosis effects on humans and—so that these would be continuing areas of the medical research that would also be in your top priority list. But could you also tell us what it would cost to do the other types of research that can be done in zero gravity uniquely and are part of the university-based research consortium so we have an idea of what that budget is?

Dr. GRIFFIN. Yes, Senator, we will. And I will indicate to you what our priorities would be for the research that would continue and what we would plan to delay or defer in order to accelerate CEV.

Senator HUTCHISON. That would be very helpful. My last question in this round would be, obviously you are focusing on the CEV. You have said that the Shuttle itself is flawed, perhaps because of the heavy payload. I don't know all of the reasons why. But my question is this: How do you propose and what is your priority ranking for getting payload to the Space Station or perhaps even beyond to the Moon, if that is necessary, if you do not have a Shuttle that can carry payload? How do you plan to do that? And what are you—where is that in your priority list when you do not have a Shuttle anymore?

Dr. GRIFFIN. Senator, that is an excellent question. Thank you. Of course, we have been getting cargo to the Space Station for the last two-plus years while the Shuttle has been grounded, through the good offices of our Russian partner, with a series of progress flights. The progress system is limited in capacity, but it does feature the capability to do an automated proximity operations flight plan and automated rendezvous and docking with the Space Station.

The United States needs to develop that capability, and we will be doing so. Later this summer, perhaps early fall, we will be releasing an RFP in the crew and cargo line—I think you will find that in our budget—that is intended specifically to address the provision of Space Station cargo resupply, up-mass, if you will, by commercial means, commercial contracts to all carriers.

In addition, the Exploration Systems Architecture Study (ESAS) we are doing over the summer will define a path by which the government can meet government requirements for cargo to Space Station, should commercial providers fail to show up. So we will have two paths.

Going forward, our budget baseline will assume that commercial cargo carriers will be able to provide those services to the station.

Senator HUTCHISON. So bottom line, you do intend for us to have some capability, besides depending on any other partner, for that responsibility.

Dr. GRIFFIN. Absolutely.

Senator HUTCHISON. Thank you.

Senator Nelson?

Senator NELSON. Thank you, Madame Chairman.

What happens if the CEV is not ready by 2010 when your plan is to scrap the Shuttle?

Dr. GRIFFIN. It is my job to convince you that we will have a development plan for CEV that has it ready by 2010, or as soon thereafter as we can we will say the date and we will try to hold to it. I will try to convince you, as we go through the next few years together, that we are holding to that plan. In part, the definition of what the CEV is needs to be done with the constraint that it be buildable, that it be an executable program and can be fielded shortly after the Shuttle's retirement.

Senator NELSON. And in that plan would be the plan for the orderly transition from one to the other?

Dr. GRIFFIN. Exactly. Yes, sir.

Senator NELSON. Of course at that point, we assume that the Space Station would be up in full bloom and running with a complete complement of astronauts doing research. Therein is another reason why we need the follow-on vehicle ready, so that there is not this hiatus. Given the fact of our experience back in 1975 in the last Apollo, it was Apollo–Soyuz, we thought we were going to fly the Space Shuttle in about 1978. And it did not fly until 1981.

A part of that work force was effectively utilized so that they did not have to lay them off and that that corporate memory was all there. What are your plans, what is your thinking about, if there did occur this hiatus, of how you would keep that team together?

Dr. GRIFFIN. Senator, I lived through that period as a working engineer and remember it well. It is not one of my more pleasant memories from my 35 years in the space business. So one of the reasons I so strongly support the concerns which have been expressed about minimizing that gap in human space flight capability is that I frankly do not want to live through that experience twice.

Our primary contractor in Space Shuttle, space flight, launch operations, launch preparations is, of course, the United Space Alliance. We work with that contractor every day, every week. We have very close ties with them. We are pleased with the work. It is our goal going forward in developing a transition plan from Shuttle to CEV to be hand in glove with our USA contractor to effect the most orderly transition that we can.

As I said briefly in my opening statement, we have studied lessons learned from the Titan IV transition. We have gone back and studied lessons learned from the Saturn Apollo to Shuttle transition. Some of those lessons are good ones and some are things to be avoided. We are paying attention.

There are two basic issues. Any launch system—I referred earlier to the fact of, the known fact of, it takes about $4.5 billion to keep the Shuttle going whether you fly any flights or not. The new system must have lower fixed costs or we, the United States, will not have effected any improvement. Lower fixed cost means a smaller work force in the sense of a standing army. So we want to shift money from what it takes merely to launch payloads into more exciting and new things that we want to do. So some work force will be transitioned going forward and other elements of the work force must be transitioned to new activities. Otherwise we would do nothing new.

That program must be managed as carefully and in as much of a forward-looking sense as we possibly can. That is our every intention.

Senator NELSON. And an additional computation here is that you will have a full-up, robust, internationally participated in Space Station that you want to utilize. And suddenly, if you stop the Shuttle and you do not have the follow-on vehicle to service that Space Station, you cannot use all of that investment of multiple tens of billions of dollars up in the heavens. For example, what would we use as a lifeboat? I guess we would have to use the Soyuz. Well, then therefore, you have to drop the level of the crew so you are not using that super structure up there that we have invested so much in.

What is your thinking there?

Dr. GRIFFIN. I cannot but agree with you. If we have a station, we need to be able to use it. I do not know how to say in enough different ways that I am convinced that your concern about minimizing such gaps in access are on target. We at NASA are working to eliminate that and to provide a credible plan for doing so.

Senator NELSON. Well, I commend you on what you have already done, which is accelerate the CEV and see if that is doable. But that then begs my next statement, which is, if it cannot be accelerated, then maybe it is in the interest of the United States to extend the Shuttle.

Dr. GRIFFIN. Sir, if we do that, then we face the circular problem. I have a hole in my gas tank, but the money I have to spend buying the gasoline prevents me from paying the mechanic to fix the tank.

Senator NELSON. Well, then——

Dr. GRIFFIN. I have to retire the Shuttle in order to have the money to do the things that you and I both want to do.

Senator NELSON. Understandably. But if the development CEV does not occur in the expeditious way that you hope and that you are giving leadership to, and we commend you for that, you have to have a plan B. Otherwise we are going to waste all that asset up there.

Just a concluding thought here, Madame Chairman. In a previous hearing we had brand new testimony about the promise, for example, that I did not know of the experiments that are going on on protein crystal growths, experiments that were made 20 years ago and of which there was some question of whether or not it was financially feasible to do that in orbit, as opposed to on Earth. But now that we are seeing new promise, as was the testimony, I still have not received those answers. And I would like this statement to NASA, please get those answers back to me.

But if there is that promise of medical breakthroughs on such things as protein crystal growth on orbit, then that is just all the more reason why we need to keep that International Space Station functioning.

Thank you.

Senator HUTCHISON. Thank you. I agree.

I would like another round, but we are told that we have to end at 11:30. And therefore, I am going to ask you to come back and see us very soon and stay in touch with us. And we will call our second panel.

Dr. GRIFFIN. I am at your disposal.

Senator HUTCHISON. Thank you very much.

Dr. GRIFFIN. Thank you.

[Pause.]

Senator HUTCHISON. OK. If you would, I would like to ask you, since we are on a very tight timeframe, if you would each speak 2 minutes, summarize all of your statements with your major points. And then we will have a few minutes left for questions.

I would like to first ask Mr. Michael McCulley, who is the President and Chief Executive Officer of United Space Alliance.

STATEMENT OF MICHAEL J. MCCULLEY, PRESIDENT AND CEO, UNITED SPACE ALLIANCE

Mr. MCCULLEY. Thank you for the opportunity to speak on this very important subject. It is my privilege to be representing the 10,000-plus men and women of the United States Alliance. And I can tell you that virtually everything we are doing these days is focused on supporting NASA in the Return to Flight effort.

But having said that, we all realized when the President gave his vision speech last January, there would be a new world for USA and that was this world of transition. And so within minutes of the speech, we started transition planning. It goes on today. It is a transition that must be carefully and proactively managed and led.

NASA and USA have taken measures to address that transition in terms of workforce, facilities, hardware, equipment, test assets, and also the supplier base. The GAO has also weighed in on this. And I will not quote, as I was going to do, but they have done an excellent initial report on our efforts to start managing this transition.

In addition, NASA and the NASA industry partnership through the Space Operations Summit have also begun transition planning, including all of those things that I mentioned earlier. It also would include retention, recruitment of critical skills, how we dispose or preserve the assets. It has resulted in some changes in the Shuttle program office that are proactive attempts to get a jump on this transition.

In addition, over the years, USA, owned by Boeing and Lockheed Martin, has had excellent results in previous times when there has been either an overage or a shortage on one company's part or the other. We have developed a really good procedure of transferring employees back and forth. We have used it very successfully. And I would anticipate that we will have that in the future, as well.

In addition, Dr. Griffin mentioned the Titan program. I have been paying very close attention to the Titan program, which flew its last flight in Florida last month, I have met with the contracting officers to understand what the Air Force did with Lockheed Martin is in contract to make changes to retain critical skills through the last flight. The Space Flight Operations Contract has a follow-on provision that we are working on now with NASA. I would anticipate that NASA would require us in that contract to do more proactive planning on how we are going to work our way through this transition and to insure that the last Space Shuttle flight is just as safe as the next Space Shuttle flight.

Of course, the execution and timing of all these measures depends on a number of different things, and a number of different requirements. I am sitting here with a great deal of uncertainty right now, but I am pleased that Dr. Griffin has put his teams in place and has said the summertime is their deadline. So I anticipate by the summer or the fall I will have a much better idea of what I need to do with specific goals, requirements and planning horizons.

You had asked about the industrial base and asked me to comment on that. It is a great question, because many of the skills and certifications that are in the Shuttle program are unique to that program. As we begin to fly down, we have a vendor base out there that we have to carefully manage. Some of their contracts have options like lifetime buys on materials or products. Other times we do not have that option.

For example, the United Technologies Company builds the fuel cells for the Space Shuttle. Well, we are not going to order any more fuel cells. So we are a very small part of their business. But I need that skill set in place up until the last landing on the last flight. And so our contractual arrangements need to reflect that. And so it changes our contracts and the way we manage contracts. We are also working that proactively.

In summary, we were created for one customer, and that is NASA. I have 10,000-plus experts, including myself and my management team, focused on supporting that customer.

Senator HUTCHISON. Thank you very much.

[The prepared statement of Mr. McCulley follows:]

PREPARED STATEMENT OF MICHAEL J. MCCULLEY, PRESIDENT AND CEO, UNITED SPACE ALLIANCE

Madam Chairwoman, Ranking Member Nelson, Members of the Subcommittee. I am Mike McCulley, the President and Chief Executive Officer of the United Space Alliance (USA).

Thank you for giving me the opportunity to address the Subcommittee on current Space Shuttle operations and the timing and scope of the planned retirement of the fleet.

It is my privilege to represent the 10,400 men and woman of USA located primarily in Texas, Florida, and Alabama.

USA is responsible for the day-to-day operations of NASA's Space Shuttle system, excluding the propulsions elements managed by the Marshall Space Flight Center. USA was formed in 1996 through consolidation of 29 Shuttle contracts into one single contract and organization.

The foremost focus of USA and its employees today is the safe return to flight of the Shuttle. Beyond this imperative, we are also working with our NASA customer to face the reality of Shuttle retirement and do the necessary planning to ensure an efficient, timely and prudent transition to the CEV.

As the Subcommittee Members are aware, the current exploration plan contains a gap in U.S. human space flight capability between the projected retirement of the Shuttle and the availability of a fully operational Crew Exploration Vehicle (CEV) and its new launch system. This so called gap has a number of associated issues including U.S. reliance on foreign nations for human access to space, the need for a heavy-lift cargo launch capability for cargo to and from the International Space Station, the potential loss of vital workforce skills and experience, and related impacts to the U.S. industrial base.

Retention of the critical skills required to fly safely and successfully throughout the remaining life of the Shuttle program and the ability to transition those workers with the necessary skills and competencies to the next generation of launch vehicles, remains a top priority for NASA and USA. The new NASA Administrator, Dr. Michael Griffin, has testified that he has established an Exploration Systems Architecture Study team to examine ways to accelerate the development of the Crew Exploration Vehicles in order to minimize any gap in the U.S. capability for human space flight.

USA understands and fully appreciates the need to plan for the future of our critically important workforce and has taken steps to develop such a plan. We are also working with NASA on all aspects of transition planning including: workforce, facilities, hardware, equipment, test assets, and supplier base.

Transition

There are over 20,000 NASA and contractor employees working on the Shuttle Program. As the Shuttle is retired, it is expected that a number of contractor and civil servant employees will initiate personal retirement, while a number will remain, to continue to support human space flight by moving to the new exploration programs. However, as currently envisioned, the number of employees available for this opportunity could be limited both by the gap between Shuttle retirement and CEV operational capability, and by the exploration emphasis on increased operational efficiency. Although there remain uncertainties with respect to specific plans for implementation of the exploration Vision, we are continuing to assess options for the future to ensure a seamless transition for our employees while meeting the needs of our NASA customer.

Following President Bush's announcement of the Vision for Space Exploration, NASA, USA and other aerospace industries began an early initiative to identify and prioritize solutions to address both fly-out and phase-out of the Shuttle program. The Integrated Space Operations Summit (ISOS) was held earlier this year to identify the issues associated with transition planning for workforce, facilities and industrial base. The Summit considered the risks and challenges for the retention and recruitment of a critically skilled workforce as well as strategies for preservation or disposition of space flight assets, which include real property, equipment, tooling, and test sets. Since the Summit, NASA's Space Shuttle Program Office has initiated a transition plan and formed an asset management working group.

As reported by the Government Accountability Office (GAO) in its March 2005 Report entitled, "Space Shuttle: Actions Needed to Better Position NASA to Sustain Its Workforce through Retirement," p.12:

> "United Space Alliance has taken preliminary steps to begin to prepare for the Space Shuttle's retirement and its impact on the company's workforce. For example, the company has begun to define its critical skills needs to continue to support the Space Shuttle program; has devised a communication plan; contracted with a human capital consulting firm to conduct a comprehensive study of its workforce; and continues to monitor indicators of employee morale and workforce stability. While these efforts are underway, further efforts to prepare for the Space Shuttle's retirement and its impact on their workforce are on hold until NASA first makes decisions that impact the Space Shuttle's remaining flight schedule and thus the time frames for retiring the program and transitioning its assets. Once these decisions have been made and United Space Alliance's contract requirements have been defined, these officials said that they would then be able to proceed with their workforce planning efforts for the Space Shuttle's retirement, a process that will likely take 6 months to complete."

United Space Alliance has retained Watson Wyatt's Human Capital Practice to benchmark industry's effective employee retention programs and to conduct a comprehensive study of USA's human resource programs as they relate to current and anticipated workforce retention objectives. This study is focused on the current situation, as well as projections out 6 years, regarding human capital investments and risk mitigation, including, alignment, resources, turnover, selection, retention, transfer-of-knowledge and investments. The results of this study will be available this year, thus allowing implementation, as appropriate, well in advance of 2010.

USA may have the ability to transfer valued workers into its owner companies, Boeing and Lockheed Martin. USA has been successful in the past, placing employees at those companies and in assisting employees in transitioning to other space-related businesses.

USA's human capital systems are monitored continuously with special emphasis on critical skills required and addressing identified gaps in these skills as a result of attrition and retirements. These processes will continue with heightened emphasis throughout the remainder of the Shuttle Program.

USA will also continue to conduct annual compensation and benefit surveys and studies that address our labor market competitiveness and will continue to monitor indicators of potential issues regarding workforce morale and stability.

The execution and timing of skill retention and transition measures will depend entirely on the timing, sequence, and options chosen for transitioning from Shuttle to future exploration programs. Until we know more about these variables, it will be difficult to predict specific impacts. For instance, if NASA decides to pursue a launch vehicle based on current Shuttle components, then the impacts would be quite different from those of a vehicle program that does not involve Shuttle components.

USA is actively evaluating and pursuing new business opportunities in space operations, such as CEV, that could utilize the unique skills and experience of the current Shuttle workforce. USA is also participating on the industry team evaluating ways to meet future launch system requirements with Shuttle Derived Launch Vehicle options.

Our Business Development Office is working to position USA to participate in all future human space flight operations. With unrivaled capabilities in terms of safety, experience, performance and innovation, combined with a diversity of skills, USA is uniquely positioned to play a major role in future human space programs.

Industrial Base

NASA's Space Shuttle budget pays for hardware, engineering, training, software development, Shuttle processing and many other things that go into flying the Shuttle. As the program winds down, there are elements that could phase-out of production, such as, the External Tank, Space Shuttle Main Engines, and Reusable Solid Rocket Motors. However, all of these major Shuttle system elements, which are managed by other NASA prime contractors, may be needed if Shuttle Derived Vehicles are selected for the exploration transportation system.

Retaining critical supplies for the Shuttle must be a well thought out, carefully managed process. One approach is to use lifetime buys for consumable products that will last to the end of the program. However, there are some supplies that cannot be purchased in lifetime buys and cannot be transitioned to other suppliers. In those cases, it will require keeping a supplier on contract until the end of the program to support refurbishment requirements, provide on-going technical support, and retain process certification. NASA and USA already have many such contracts in place. An example is the Lockheed Martin contract for tooling and certified technician maintenance to refurbish and manufacture the Reinforced Carbon-Carbon (RCC) Wing Leading Edge. It is not likely that we will need additional RCC components however, we will require continuing support in the areas of testing and evaluation of flown hardware, failure analysis, and repair. A similar situation exists with United Technologies Corporation, which provides the Shuttle fuel cells. Maintenance of critical skills to support this hardware component through the last flight is critical.

Many of the skills and certifications needed to support the Shuttle Program are unique to the program. It is difficult to estimate the cost or schedule impact to the Shuttle or to the CEV should those skills begin to deplete. We continue to be a very small part of many of our suppliers' business bases so, for some, there is little incentive to invest in or maintain these skills. As we move closer to the last Shuttle flights and the corresponding reduction in hardware procurement, this base could become more fragile.

Manifest

You have asked that I also address current Space Shuttle operations and manifest.

NASA and its industry team have embarked on a proactive Return To Flight Plan, which not only responds to the CAIB recommendations, but also "raises the bar" by addressing other safety concerns. The Columbia Accident Investigation Board initially published 15 recommendations for various improvements to be completed before Space Shuttle Missions could resume. Of the original 15, 12 have been completed and 3 are in the process of being completed.

NASA and its industry team have made improvements in technical excellence, communications and decision-making, improved the External Tank to reduce debris-shedding, instrumented the Shuttle wings to detect any debris hits during ascent and amassed an array of ground-based and space-based imagery detection hardware that will give experts the ability to know if any debris hit the orbiter. If so, NASA is developing in-flight repair techniques and we have procedures to safely protect the crew onboard the Space Station if necessary.

NASA and its contractor team are committed to flying the Shuttle only when all the risks have been appropriately mitigated. We are working with NASA to support the initial Return To Flight mission, STS–114, which is currently planned for the July 13–31 launch window.

At present, 28 Shuttle flights are baselined in the manifest-18 for assembly, 5 for utilization and 5 for logistical support. Relative to returning to flight, the first two flights, STS–114 and STS–121, carry much needed cargo to the Space Station and importantly serve as test flights of the improved Shuttle system. Testing will be conducted using the Orbiter Boom Sensor System (OBSS) to closely examine the Shuttle's Thermal Protection System and to assess on-orbit repair options and techniques for tile and the RCC. The remaining 26 Shuttle missions are manifested as Station assembly and outfitting flights.

The International Space Station (ISS) is currently dependent on the Space Shuttle for assembly. We are still planning to fly the 28 flights manifested including the 18 identified as assembly flights but as the new NASA Administrator testified, NASA is currently examining alternative configurations for the Space Station. If changes to the manifest are made, we will work with our NASA customer to evaluate the impact to the overall program, our workforce and the supplier base.

Operations

United Space Alliance is the leading human space flight space operations company in the world with experience in all aspects of ground processing, mission operations and planning, major system integration, and in-flight operations of multipurpose space systems. Through its support of the Space Shuttle and ISS programs, USA has developed an unrivaled combination of experience and capabilities in space operations. Our workforce and our supplier base have the spectrum of skills to support NASA's current and future human space flight programs including:

- Mission, manifest and trajectory planning and analyses
- On-Orbit assembly, payload deployment and servicing
- Extravehicular activity planning and execution
- Rendezvous and proximity, operations and docking operations
- Space logistics and supply chain management
- Space operations software engineering
- Advanced space flight technology
- Launch and recovery operations
- Launch vehicle and flight hardware processing
- Mission control operations
- Space systems and crew training
- Sustaining engineering
- Flight crew equipment preparation and maintenance.
- Large scale, complex systems integration
- Subcontracts management

Conclusion

United Space Alliance is committed to returning the Shuttle to flight and to supporting a seamless transition from the current program to future exploration programs. Workforce morale is high as the first step in the Vision draws near: the launch of Space Shuttle Discovery mission STS–114. We are committed to supporting NASA in our joint goal of making each flight safer for the crew than we believed that last one to have been.

We also support NASA's goal to undertake a journey of space exploration over the next several decades as outlined in the President's Vision for Space Exploration. We understand that the retirement of 3 capable and space-worthy Space Shuttle orbiters is needed in order to move the Vision forward. Our exceptional workforce is committed to these goals and deserves our utmost consideration in the transition to a new system for space exploration.

Let me again thank the Subcommittee for the opportunity to come before you today. I would be pleased to answer your questions.

Senator HUTCHISON. I appreciate the very difficult job you are going to have in the, well, next 5 years to 2010 to maintain all the capabilities and yet knowing what a final date is, when that final date is set. Thank you very much.

Dr. Joan Johnson-Freese is the Chairman of the Department of National Security Studies at the Naval War College.

Dr. Freese, welcome.

STATEMENT OF DR. JOAN JOHNSON–FREESE, CHAIRMAN, DEPARTMENT OF NATIONAL SECURITY STUDIES, NAVAL WAR COLLEGE

Dr. JOHNSON-FREESE. Thank you, Senator Hutchison, Senator Nelson. Thank you for inviting me to speak with you today on the critical issue of the future of manned space flight, specifically the strategic environment of human space flight. I have worked on space policy issues for more than 20 years from many perspectives. And based on that experience, I feel that human space flight is not just something the United States should remain actively engaged in; it is an area strategically it must retain leadership in.

In May 2003, there was a newspaper op-ed piece entitled, "Next Huge Space Shot, China." It began with the sentence, "Once upon a time, we ruled the universe. Now we're second-raters in space." It concluded with the sentence, "We have forfeited the last frontier." Convoluted interpretations of events and leaps of reasonings, like those expressed in that piece, unfortunately are not uncommon.

Consequently, it is not really surprising that many people have concluded that with one 21-hour manned space flight, China has catapulted ahead of the United States in overall space capabilities, especially human space flight capabilities. While it is sadly true that the U.S. has not chosen to pursue human space exploration in a timely and concerted manner, as many people hoped it would, we are certainly by no means a second-rate space power because it has pursued a different priority and slower pace. But there is perception.

Human space flight, human space activity has always had a strong symbolic significance. Because of the early and spectacular U.S. successes in the manned space flight arena, winning the race to the Moon, the U.S. has heretofore been considered the unchallenged leader in human space activity. Unfortunately, again, that perception has been slipping.

Now with the Chinese willing to play the tortoise to the U.S. hare, there is a very real chance that the U.S. will be outpaced by commitment demonstrated by consistency rather than speed or substance, creating the perception that the U.S. is forfeiting its leadership. There are many reasons this should not be allowed to happen. And I would be happy to go into them with you.

But as the sole super power, the U.S. must lead the way to the future. How we lead the way is critical as well and I think offers the United States an opportunity to demonstrate inclusive leadership toward generating soft power critical to advance U.S. policies.

The U.S. cinched leadership in human space flight early on. Now the strategic imperative is to maintain it.

Senator HUTCHISON. Thank you very much.

[The prepared statement of Dr. Johnson-Freese follows:]

PREPARED STATEMENT OF DR. JOAN JOHNSON-FREESE, CHAIRMAN, DEPARTMENT OF NATIONAL SECURITY STUDIES, NAVAL WAR COLLEGE

Last week, I challenged my class of 78 college students to, first, name three of the Apollo astronauts, then, three current astronauts. Some could name three Apollo astronauts, none could name three current astronauts, or even one. The Apollo program represents a glorious part of American history. Neil Armstrong stepping off planet Earth and onto another celestial body was both a shining moment for Americans, and a spiritual moment for all mankind. America held the attention and admiration of the world because it dared to venture into the Heavens. But too often America is a crisis-response society. Politically motivated to go to the Moon by the Soviet launch of Sputnik, in less than a decade the United States was successful beyond anyone's wildest imagination. Unfortunately, however, we did not choose to stay or to continue the journey. Instead, we came home and spaceflight has since been confined to the celestial driveway. Now, except for a few die-hards, the American public shows more interest in its space museums than space exploration. But, I will suggest, allowing even the perception of U.S. leadership in human space to slip has negative strategic implications for the United States.

Americans take great pride in space achievements. Even at the height of the Apollo era though, opinion polls showed that the public sees space exploration as a good thing to do, but expendable when prioritized against other demands for federal funding, like health care, education, schools and defense. Subsequently, the human space program has been struggling since Apollo to find a *raison d'etre* with both the public and politicians sufficient to carry human spaceflight out of the celestial driveway and into the street. The difference between Apollo and all subsequent human space visions has been the goals. Whereas Apollo had a strategic goal—"beat the Russians"—programs since have had science and exploration as their goals and unfortunately, these goals have not proven sufficient to be competitive with other demands for federal funds.

While many countries have shown interest over the years in developing autonomous human space programs, besides the United States only Russia and China, as of the October 2003 launch of the first Chinese taikonaut, have been successful. The Russian human space program was rescued from becoming moribund when it merged with NASA's human program to develop the International Space Station (ISS). Russia is still, however, unable to pursue new high-cost initiatives on its own, due to both economics and because they have learned that developing and maintaining support for a human space program is hard in democracies. While the European Space Agency (ESA) and countries like Japan and India likely have the technical wherewithal to have a successful human space program, they lack the requisite political will. In a Catch-22 scenario, however, having to always play a supporting role to the United States makes it even more difficult to garner public support and political will for human space activity. While Japan has long talked about a human space program, being responsible to an electorate, bureaucratic politics, economics and a cultural adversity to risk will likely keep them Earthbound. India too, as a democracy, remains constrained by public perceptions of priorities lying elsewhere. It is only because China's program is driven from the top that it has successfully been carried to fruition. So why is China, a country with 1.3 billion+ people, willing to devote significant resources to human spaceflight capability?

The Apollo program demonstrated the benefits that accrue to a nation able to claim a human spaceflight capability. In the movie *Apollo 13* Tom Hanks shows a Congressional delegation around Kennedy Space Center pointing out constituent jobs in high tech fields that were politically distributed to all fifty states. Jobs are always a valued program benefit. Americans expressed interest in science and technology education unmatched either before or after Apollo. Technology developed for space translated into economic development. Dual-use technology with both civil and military applications was developed. And finally, America enjoyed the prestige of "winning" the space race against the Soviet Union, which translated into a unifying pride during the contentious Vietnam War era, and also drew Third World countries to our side during the Cold War when East-West blocks competed for support.

Those same benefits, jobs, education, economic development, dual-use technology and prestige are still motivating factors for space activity. Since the 1950's, Europe has pursued space under the premise that space activity generated technology, technology generated industry, and industry led to economic development. China learned from the Apollo playbook as well. Training and employing workers in high-technology aerospace jobs in China keeps large numbers of people employed, which is a Chinese priority. It also demonstrates to the world that China is able to, as one Chinese commentator put it, "make more than shoes," thereby supporting their overarching economic development goal by attracting global industries to China. China is also experiencing growth in science and engineering education programs at unprecedented levels. China is clearly interested in modernizing its military, and, again learning from the U.S. playbook, China has seen the benefits space can yield in force enhancement capabilities. And finally, there is prestige. Prestige takes on two dimensions for China: first, domestically it bestows credibility on the Communist government much in the same way bringing the Olympics to Beijing does. In regional and international terms, prestige translates into techno-nationalism, where perceived technical prowess is equated to regional power. This is particularly important to China, which has been working hard and been largely successful at using economics and soft power to transform its regional image from that of the bully, to a rising power that countries can work with. For countries like Japan and India, these perceptions are important.

Speculation about an Asian space race floats on the wind, but it is unlikely. After the Shenzhou V launch in October 2003, the Indian science community claimed it too could have accomplished such an achievement, but had simply chosen not to. That response was intended to quell concerns from both the Indian public and politicians about China's technical prowess compared to India's techno-nationalism. Initial Japanese responses to the launch varied. Space officials downplayed the technical significance of the event, while nonetheless congratulating China. A Japanese official spoke to the media directly in geostrategic terms. "Japan is likely to be the one to take the severest blow from the Chinese success. A country capable of launching any time will have a large influence in terms of diplomacy at the United Nations and military affairs. Moves to buy products from a country succeeding in human space flight may occur."[1] One woman on the street was quoted in Japanese media coverage as saying, "It's unbelievable. Japan lost in this field."[2] While Japan's "losing" to China through the Shenzhou V launch was more perception than reality, China's success juxtaposed against power failures on both the Japanese environmental satellite Midori-2 and on its first Mars probe, Nozomi, as well as the November 2003 launch failure of two Information Gathering Satellites (IGS), resulted in calls for a re-examination of the Japanese program. However, because of the problems initiating and sustaining human space programs in democracies, combined with unique internal politics in both countries, the initiation of an autonomous human program in either Japan or India is unlikely.

With China's entry into the exclusive human spaceflight club, the strategic gameboard was put in motion. Whereas the United States has pursued a path of simultaneous cooperation and competition with other countries in various aspects of space, such as cooperating with Europe on ISS but competing in the commercial launch field, with China the U.S. approach has been purely competitive. China has been excluded from partnership on the International Space Station, for many years their "brass ring." The reasoning for the U.S. purely competitive approach has been technical and political: seeking to stop China from acquiring sensitive dual use technology, concern that China will be the next U.S. peer competitor, and not wanting to support the largest remaining Communist government in the world, especially one charged with human rights abuses and other practices averse to democratic principles. While such an approach may be virtuous, realities are such that it increasingly appears counterproductive.

We have to face an uncomfortable fact here: a country whose interests may very well some day conflict with our own is going to pursue a line of technological development that could enhance its ability to challenge us through multiple venues. And they are going to be aided in this by other countries, whether we like it or not. While the U.S. seeks to contain China, much of the rest of the world is eager to work with China, thereby negating much of the impact the United States is trying to achieve, and indirectly encouraging activities not necessarily in the interest of the U.S. Other countries, allies, have often held passive-aggressive feelings toward space partnerships with the U.S.: welcoming and grateful for the opportunities, while resenting being inherently consigned to a supporting role, and feeling that

[1] "China's launch of manned spacecraft welcomed in Japan," *Japan Economic Newswire*, 15 October 2003.

[2] "China's launch of manned spacecraft welcomed in Japan," *Japan Economic Newswire*, 15 October 2003.

U.S. partners are often treated more as secondary participants or sub-contractors on projects. Working with China gives them a chance to level the playing field.

There is a fairly widespread perception among the U.S. and international media, and a disconcerting number of the American public, that a human space race between China and the U.S. is either already underway or inevitable. China's one human launch into space clearly demonstrated the maturity of Chinese space engineering. Successfully launching a rocket is not, however, a scientific breakthrough—the know-how has been in textbooks for more than fifty years. It does demonstrate the careful attention to literally thousands of minute engineering details. But by no means has China leapfrogged over U.S. capabilities.

China has ambitious human space goals, but a modest, incremental implementation plan. Officially, their current human program is a three part plan: man in space, a space laboratory, and a space station. Beyond that, their ambitions for the Moon and Mars are facing the same funding and political hurdles as NASA faces in the U.S. In a November 21, 2004 press conference Ouyang Ziyuan, the lead scientist of their lunar program, talked about the costs and benefits of space, referencing the Apollo experience.[3]

> "The lunar exploration project will spur high tech development, and I cannot calculate how much return there will be on that investment of 1.4 billion, but the Apollo project spurred the scientific, technical, economic military and other development of the 1960s, produced over 3,000 new technologies of all types with applications useful in everyday life, and was not only responsible for America's leading position in science and technology, but it produced enormous political and economic change.
>
> It is estimated that for every dollar invested there was an economic return of 4–5 dollars. We learned a lot about the Moon, the Earth, and the Sun that is impossible to calculate in dollar terms. From ancient times to the present China has had the legend of Chang E, and you could say that going to the Moon started with China, but to today we have still not left the Earth. The lunar exploration project will have an incalculably valuable effect on the ethnic spirit and motivation (of the Chinese people) and I ask you, how much is that worth?"

While having to justify expenditures, the Chinese will continue their quest for space as long as sufficient domestic and geostrategic benefits accrue, and they will solicit international partners.

China's human spaceflight program was largely indigenously developed, but based on proven designs adapted to make them their own. They have openly stated their appreciation for the work of the former Soviet Union toward making their own human spaceflight program a success. China understands the benefits, fiscal, technical and political, of cooperation. In the same November 21, 2004 press report, Ouyang Ziyuan spoke about cooperation. "International cooperation (in space exploration) is a necessary development, no single country has the ability to complete (this undertaking) by itself. Landing on the Moon is an affair of the entire human race, and we should make our contribution on behalf of the Chinese race, fulfill the responsibility of the Chinese race. We want to learn together with others, not close ourselves off and go our own way." A pragmatic move for the Chinese, there were interested takers to invitations for cooperation.

China has spent approximately $2.2 billion on its Shenzhou program, whereas NASA's annual budget is in excess of $16 billion. Shenzhou V was launched in 2003; Shenzhou VI will likely be launched in 2005. From the Chinese perspective, there was no need to go any sooner, as China has been able to enjoy its new found status as the third country capable of human spaceflight, while improving its technical capabilities, and keeping spending to a manageable level. Nevertheless, China's ability to successfully launch their first taikonaut while the U.S. Space Shuttle was grounded added to the perception of China's technical prowess compared to the U.S., not an inconsequential or unrewarding benefit for the Chinese. If the Shuttle is still not flying next Fall when the Chinese launch again, the Chinese will reap further prestige and publicity at the expense of the U.S. The U.S. has historically been the reigning human space champion, but there is always interest—and even tacit support—when a spoiler overtakes, or even appears to overtake, a champion. The U.S. appears in, and to some losing, a human space race, because the U.S. has been unable to set and implement a realistic way forward, and because of U.S. political reluctance to use cooperation, historically shown successful, to co-opt and shape the Chinese space program as we have other programs. The Chinese are playing Tortoise to the U.S. Hare.

[3] See: People's Daily Website.

It has been suggested that engaging China in a space race would provide the political will for the U.S. human program to move forward, as the Soviet Union's activities did for Apollo, or that it would trigger a spending spree in China with effects similar to those experienced by the Soviet Union trying to keep up with SDI. Both are flawed analogies. During the Cold War, two competing superpowers started from the same point technologically and engaged in an engineering race. Both were motivated to compete. Now, the Chinese have no reason to "race" the United States. Chinese spending will not increase to keep up or outpace the United States either, as they fully understand it is impossible. China needs only to incrementally continue their human space program to create the perception that it is "beating" the United States. China's activities place the U.S. in a race against itself, to maintain its leadership.

Meanwhile, China will increasingly engage other countries in cooperative space activity. Technological containment of the U.S.S.R. took place in another time and under circumstances that are now impossible to replicate: there is no way to seal China off from the technologies it seeks. Our best hope, then, is to shape China's future in space, rather than watch it develop in 20 years—with assistance from others—into something that we will wish we could have diverted. China is already working with the European Space Agency on programs ranging from DoubleStar to Galileo, it worked with Russia on human spaceflight, and it is courting many Asian countries for projects involving cooperative work on environmental and disaster monitoring and management, sometimes through the Asia-Pacific Multilateral Cooperation in Space Organization (APSCO). That the EU considered dropping its arms embargo against China demonstrates that other countries do not necessarily share U.S. views about the value or necessity of isolating China. Over the long term, the reality is that China will increasingly engage partners in space activity. The question is whether the United States will choose to deflect or co-opt some of that cooperative activity in directions of our choosing?

The United States has historically and successfully employed cooperative space activities to "shape" other countries' programs; guiding them into benign areas of interest and leaving them less funds to pursue activities less in our interest. Controlled or limited cooperation has also allowed the U.S. to get a much better idea of exactly what the priorities and capabilities are in other countries. Because China's program is still largely opaque, isolating it will only limit our ability to monitor what they are doing, and perhaps even more important, their long-term intent. Technology transfer remains a critical issue. Given that stopping technology transfer to China is impossible because the U.S. does not have a technology monopoly, managing it through transfers from the U.S., rather than having China obtain it from other countries with lesser controls, becomes a pragmatic option. Further, cooperation with China on space offers the U.S. leverage in Chinese space activities, gets the U.S. out of a counterproductive perception of a space race, and offers the U.S. the opportunity to develop soft power through a human space program with a goal beyond science and exploration—strategic leadership.

Cooperation in space with China does not excuse the Communist regime from its commitment to Communism and its abysmal record on human rights. But indeed it is because China is an authoritarian state at the crossroads of its political development that it becomes imperative that America, as the world's leading democracy, step forward and help shape China's aspirations in space toward peaceful and cooperative ends rather than see them turned toward more threatening ideological or military goals. It should also be pointed out that attempting to draw linkages between space cooperation and other foreign policy goals, like human rights, is unlikely to be successful. The U.S. tried with the Soviet Union and only became frustrated. The U.S. can use space cooperation to co-opt, or shape, Chinese space activity. That is a worthy goal in itself.

An inclusive cooperative human space program returns to the Apollo model, a program with a strategic goal, but this time based on cooperation rather than competition. Cooperation is not easy. But the ISS experience, and studies conducted by groups such as the American Institute of Aeronautics and Astronautics with long experience in cooperation models tells us there are ways to manage the issues.[4] A first step in any model is to assure that all partners have a vested interest in success, all partners fully understand their roles, and that the science and engineering goals are meaningful. We know how to do it.

Imagine if you will a few alternative, hypothetical scenarios. If the United States were to finish the ISS only to then turn it over to the partners so the U.S. could

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[4] See, for example, a recent AIAA paper by Peggy Finarelli and Ian Pryke, "Optimizing Space Exploration through International Cooperation," and the full report of the 7th AIAA Workshop on International Space Cooperation, www.aiaa.org/IntlCoop.

pursue the Moon/ Mars vision, but then got mired down in technical or political difficulties, which would not be hard to imagine, the U.S. could end up the only space-faring nation not involved in ISS. If the U.S. pursues the Moon/Mars vision with the ISS partners, but not China; it is China (the developing country) versus the rest of the (developed) world, magnifying the perceived importance of each small advancement China makes and every misstep we make. If the U.S. pursues the Moon/ Mars mission alone—other countries could see working with China as an opportunity to work on a human space program, and on a more level playing field, creating a U.S. versus China+ scenario. And finally, some have suggested that the U.S. simply forego human space activity.

The U.S. must not, however, allow human space leadership to slip away. Human spaceflight requires pushing the envelop in areas of science and engineering—in medical fields and areas of life support systems engineering, for example—otherwise potentially neglected. While direct benefits to the economy or defense from a particular program may not always be identifiable in advance, GPS, once a government program without a clear mission, has certainly demonstrated that we should not be bound by the limits of our imagination. The importance that space provides to building science capabilities generally is not unnoticed elsewhere. China, for example, is acutely aware that it has a long way to go toward becoming a science "power" and it hopes human spaceflight will accelerate its movement up the learning curve. For the U.S. to maintain its leadership position, it is therefore imperative that the U.S. stays active in space as well. It is also important to remember that human spaceflight is part of the U.S. space agenda, not the entire agenda. We need to maintain a balance in the U.S. to assure continued preeminence in all aspects of science and engineering. And finally, space represents the future. It is imperative that the United States, as the world's leader, remain the world's leader into the future.

Finally, I encourage this Committee to look into and plan for the future of human spaceflight from an "effects-based" perspective. What does the U.S. hope to achieve? Is the U.S. looking to maintain its preeminence in human spaceflight? I suggest we must. If that is the goal, realistically, we need a rationale beyond science and exploration to sustain the momentum. Competition once served that purpose but will not any longer. Indeed competition places the U.S. into a race not in its best interests. Strategic leadership of a cooperative space mission off planet Earth offers the U.S. a viable way forward toward maintaining U.S. leadership while generating significant soft power globally, soft power necessary toward such strategic goals as effectively fighting the Global War on Terrorism. I encourage this Committee to look at space from a strategic perspective, not just from a science or exploration perspective.

Senator HUTCHISON. Dr. Scott Horowitz, Director of Space Transportation and Exploration at ATK Thiokol.

STATEMENT OF DR. SCOTT J. HOROWITZ, DIRECTOR, SPACE TRANSPORTATION AND EXPLORATION, ATK THIOKOL, INC.

Dr. HOROWITZ. Thank you, Madame Chair and Senator Nelson. It is a great honor to be here today. And I appreciate the opportunity to discuss evolving Space Shuttle systems that will provide a safe, reliable, and a cost-effective method to ensure human access to space, along with heavy lift we are going to need to have to do space exploration and retire the Space Shuttle by 2010.

It has been a great privilege and an honor to have served as an astronaut on four Space Shuttle missions. So I have seen rendezvous in space, the International Space Station, and the Hubble Telescope up close and personal. And we at ATK are very excited about the President's vision and support NASA's new administrator, Mike Griffin, in his efforts to make this vision a reality.

I firmly believe that we can safely and affordably transition the Space Shuttle program to support exploration by leveraging our flight-proven and human-rated elements that exist today. NASA needs a safe, reliable, and affordable method of transporting crews to and from Earth orbit and heavy lift for cargo. That is the bottom line.

And I believe it is tremendously important to learn lessons from the past and apply them to the future of human space flight. The Columbia Accident Investigation Board had concluded, and I quote, “The design of the system should give overriding priority to crew safety, rather than trade safety against other performance criteria, such as low cost and reusability.” And I totally agree with this conclusion.

So there are two things we have to address, which is heavy lift and crew transport. Albert Einstein once said, “Make everything as simple as possible, but not any simpler.” So we have concepts for a simple, safe way evolving, for example, using the solid rocket booster and maybe a J–2S from the Apollo program or another engine to safely get the crew to and from orbit. In fact, a recent study has shown that this particular launch vehicle has a forecasted crew safety level of more than an order of magnitude safer than today’s Shuttle.

We also have tremendous capabilities that we can utilize to support our exploration vision. The propulsion system, for example, as has been said before, already today propels 240,000 pounds to low Earth orbit. That is over 100 metric tons. So we have a tremendous capability today. One of the things that I do as I travel around the country sharing the adventures of flying in space, is I point out that it is not the thrust of the solid rocket motors and the Space Shuttle main engines that propel us to space, but it is the dedication, hard work, hopes and dreams of the many skilled and talented people that develop, manufacture, and prepare these systems that carry us to orbit.

Transitioning this workforce to support exploration is going to be key to our success. In summary, we do have a safe and a simple solution that we can have soon. We owe it to our children and future generations to do so.

Thank you very much for this opportunity. And I would be pleased to answer any questions you may have.

Senator HUTCHISON. Yes. Thank you very much.

[The prepared statement of Dr. Horowitz follows:]

PREPARED STATEMENT OF DR. SCOTT J. HOROWITZ, DIRECTOR, SPACE TRANSPORTATION AND EXPLORATION, ATK THIOKOL, INC.

Madame Chair and Members of the Subcommittee, thank you for the invitation to appear before you. I appreciate the opportunity to discuss evolving the Space Shuttle systems, and in particular leveraging the hardware, infrastructure and people to minimize development schedules and to provide a safe, reliable, cost effective method to insure human access to space along with heavy lift for exploration when we retire the Space Shuttle in 2010.

I have had the honor and privilege to serve our country as an Air Force F–15 fighter pilot, test pilot, and NASA astronaut on four Space Shuttle missions as a pilot and commander including a microgravity/science mission, Hubble servicing mission, and two missions to the International Space Station. Upon retiring from NASA and the Air Force I joined the ATK Thiokol team as the Director of Space Transportation and Exploration. These experiences, coupled with a Ph.D. in Aerospace Engineering from Georgia Tech, have provided me with a unique perspective on what it takes for our team to conduct successful human space flight missions.

We at ATK are excited about the President’s Vision for Space Exploration and fully support NASA’s new administrator, Mike Griffin, in his efforts to make this vision a reality. I firmly believe that we can safely and affordably transition the Space Shuttle program to support the Exploration program by leveraging the flight-proven and human-rated elements that exists today. This will enable us to retire the orbiter, and eliminate any gap in U.S. Human Space Flight capability. If we can start soon, we can fully meet the demanding needs of heavy lift and crew transportation more safely, more reliably, and more affordably than with any other option by the end of the decade.

NASA's need for a safe, reliable, affordable method of transporting crews to and from Low Earth Orbit can be achieved as we move forward with exploration. But I believe it tremendously important to learn from the lessons of the past and apply them to the future of human space flight. The Columbia Accident Investigation Board concluded that "The design of the 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." I totally agree with this conclusion. Additionally, in a memo dated May 4, 2004, the NASA astronaut office offered their consensus on the future by stating: "Although flying in space will always involve some measure of risk, it is our consensus that an order-of-magnitude reduction in the risk of loss of human life during ascent, is both achievable with current technology and consistent with NASA's focus on steadily improving reliability" (Attachment 1: Astronaut Office Position on Future Launch System Safety, Memo, CB–04–044, May 4, 2004).

The first step is to realize the tremendous capabilities that already exist and that can be utilized in the future to support our nations exploration vision. The Space Shuttle propulsion systems are the most reliable systems in the world. The Reusable Solid Rocket Motors used in the Space Shuttle launch phase have flown 226 times with significant engineering, inspection, and testing supporting well understood operational margins; the Space Shuttle Main Engines have flown 339 times and have over a million seconds of testing! These reliable and proven propulsion systems coupled with the External Tank constitute the Space Shuttle "propulsive backbone" and provide us an impressive capability to lift large payloads to Low Earth Orbit. Every time we launch a Space Shuttle we send about 240,000 pounds (over 100 Metric Tons) to Low Earth Orbit! More importantly, we have the existing infrastructure and skills today to produce, launch, and operate this amazing hardware. As I travel around the country sharing the adventure of flying in space, I point out that it isn't the thrust of the Solid Rocket Motors and Space Shuttle Main Engines that propel us to space, but the dedication, hard work, hopes and dreams of the many skilled and talented people that develop, manufacture, and prepare these systems that carry us to orbit. Transitioning this workforce to support Exploration is key to our success.

By evolving the shuttle's propulsive backbone to provide a heavy lift launch capability we can engage this talented, skilled workforce, and utilize our existing infrastructure. Because the orbiter vehicle sustaining, launch processing, and associated logistics drive the cost of the existing shuttle program, removing the orbiter will result in a significant reduction in cost. The propulsion elements of the Space Shuttle program only make up a fraction of the overall costs, making utilization of these systems extremely attractive for cost, safety, reliability, and sustainability. Not only is this launch system very affordable, it is the lowest cost in terms of dollars per pound to low earth orbit.

Two primary options are being reviewed to provide heavy lift (greater than 150,000 pounds)—The first option replaces the orbiter vehicle with a side-mounted expendable cargo carrier utilizing the propulsion backbone and the same connections as the orbiter. This approach minimizes configuration changes while providing the capability to launch 170,000 to 200,000 lbs to LEO. A second option, providing capability up to 250,000 lbs to LEO, is to remove the orbiter, move the main engines below the External Tank, and add an optional second stage and cargo carrier to the top of the external tank. The modifications required for option 2 are more extensive than option 1 but option 2 has the added advantage of being able to provide larger and heavier payloads to Low Earth Orbit.

Heavy lift capability in the ranges that I have mentioned is significant in that it offers the lowest risk and highest mission reliability, and ultimately the lowest cost for exploration missions. It would take 5 to 7 launches using smaller existing launch vehicles to accomplish what a single 170,000 to 250,000 pound launch vehicle can do.

The cost of breaking the exploration missions into numerous smaller pieces to accommodate a smaller launch vehicle is cost prohibitive. Each smaller element will have to become a complete spacecraft on orbit while performing an automated rendezvous and docking and be burdened with all the systems required to survive and operate in space including power systems, thermal control systems, propulsion systems, guidance navigation and control systems, docking systems, etc. Then there is the cost of the infrastructure required to support the surge rates needed for multiple launches of smaller launch vehicles that would be required during a lunar or Mars campaign. This combined with all of the associated operational costs make the use of smaller launch vehicles for exploration missions cost prohibitive. Add to that the impact on mission reliability as a result of performing so many launches and associated on-orbit assembly operations and one quickly realizes that the chances of accomplishing multiple moon or Mars missions using smaller launch vehicles is slim to none.

A heavy lift launch vehicle eliminates costly and complex in-space docking and on-orbit assembly and all of the associated supporting hardware, testing, checkout, and sustaining operations. Most significantly, a heavy lift launch vehicle simplifies the exploration architecture driving down costs for sustaining and logistics.

In combination with the heavy lift launch capability, it is equally important to leverage existing human rated propulsion elements and focus on the safest way to put the crew in space. Utilizing a single Space Shuttle reusable solid rocket motor for the first stage of the crew launch vehicle is an ideal application of simplicity. The motor is already human rated and has an outstanding proven safety and reliability record. Add to this reusable first stage a previously developed human rated 2nd stage rocket engine, either a simplified version of the Apollo engine that took astronauts to the moon, the J–2S, or a Space Shuttle main engine and you have a very simple, cost effective launch vehicle solution, built upon human rated heritage.

Albert Einstein once said: "make everything as simple as possible, but not any simpler". The crew launch vehicle that I just described is the simplest launch vehicle that can deliver almost 50,000 pounds to Low Earth Orbit. This simplicity and use of highly reliable components results in the safest launch vehicle possible for transporting astronauts to space. In fact a recent reliability and crew safety assessment of the SRB/J–2S Launch Vehicle conducted by Science Applications International Corporation (Attachment 2: SAICNY05–04–1F, 1 April 2005) concluded ". . . the SRB/J–2S derived launch vehicle forecasted crew safety level, as measured in missions where the crew is lost in a total number of missions, is 1 in 3,145 . . ." This is an order of magnitude better than today's capabilities. Another important feature of this design is that it has sufficient performance to fly trajectories to orbit that are compatible with a crew escape system. Other launch vehicles with insufficient thrust require the launch vehicle to fly higher, steeper, and longer, exposing the crew to extensive periods (up to three times longer) where a simple ballistic crew escape is not survivable.

The other major benefit of this evolved approach is that because of its simplicity and reliance on already developed hardware, this launch vehicle can be available soon. In fact, a demonstration launch could be conducted in 2008 and be ready to fly the CEV about when the Shuttle is scheduled for retirement. We could also have the heavy lift version ready at about the same time, and by leveraging the resources of the current shuttle program we could save significant dollars. We have the talented workforce, facilities, and most of the major hardware components in hand. By evolving what we have and only developing new components where needed, we can drastically reduce the cost and schedule to provide the capabilities we need to safely transport astronauts to orbit and provide the heavy lift required to conduct space exploration.

The approach that I have described also provides a means of safely transitioning from the current Space Shuttle System to the launch system required to support the Exploration Vision. The SRB/J–2S launch vehicle could easily be used to carry crew and cargo to the International Space Station, or be used as a highly reliable payload carrier to support U.S. assured access to space requirements.

By leveraging the current Space Shuttle resources we have the ability to get astronauts to/from Low Earth Orbit, an order of magnitude safer than we do today, for a very affordable cost and on a schedule that avoids a "gap" in U.S. human space flight capability. We also have the propulsive backbone of the Space Shuttle System today that is proven and ready to provide a cost effective heavy lift capability needed to do exciting exploration of the moon and enable us to reach Mars and beyond. In summary we have a **Safe, Simple** solution that we can have **Soon**. We owe it to our children and future generations to do so.

Thank you for the opportunity to share my thoughts with you, I will be pleased to respond to any questions that you may have.

Attachment 1

NASA, LYNDON B. JOHNSON SPACE CENTER
Houston, TX, May 4, 2004

TO: CA/Director, Flight Crew Operations
FROM: CB/Chief, Astronaut Office

RE: CB–04–044, SUBJECT: ASTRONAUT OFFICE POSITION ON FUTURE LAUNCH SYSTEM SAFETY

The Columbia disaster has precipitated a thorough re-evaluation of all aspects of space flight. The accompanying paper presents the Astronaut Office position on launch vehicle safety for the next generation of human-rated spacecraft.

KENT V. ROMINGER

ENCLOSURE: ASTRONAUT OFFICE POSITION ON FUTURE LAUNCH SYSTEM SAFETY

Executive Summary

The Columbia accident, the selection of a booster for the Orbital Space Plane (OSP), and NASA's recently renewed interest in exploring beyond low Earth orbit have led the Astronaut Office to reexamine its views on launch system safety. Although flying in space will always involve some measure of risk, it is our consensus that an order-of-magnitude reduction in the risk of loss of human life during ascent, compared to the Space Shuttle, is both achievable with current technology and consistent with NASA's focus on steadily improving rocket reliability, and should therefore represent a minimum safety benchmark for future systems. To reach that target, the Astronaut Office offers the following recommendations.

The Astronaut Office recommends that the next human-rated launch system add abort or escape systems to a booster with ascent reliability at least as high as the Space Shuttle's, yielding a predicted probability of 0.999 or better for crew survival during ascent. The system should be designed to achieve or exceed its reliability requirement with 95 percent confidence.

The Astronaut Office recommends that new human-rated launch vehicle programs follow guidelines, such as those given in the Columbia Accident Investigation Board (CAIB) Report and NASA's Human Rating Requirements (NPG 8705), for safety-conscious management, requirements definition, concept development, and design selection.

The Astronaut Office recommends that NASA specify and maintain a set of formal, standardized, complete methods and processes to be used in predicting the reliability of human-rated spacecraft, and identify or create an independent body to verify those analyses.

The Astronaut Office recommends that the test program for the next human-rated launch system demonstrate its reliability through vigorous ground and flight testing of components and systems. The value of each test should be leveraged by proving a safe envelope larger than that expected during operations and by using flight data to validate system reliability models. After completion of the formal test program, the vigilance applied during testing to data gathering, analysis, and flight constraints should continue to be applied during operations. Reliability should be continuously reassessed.

The Astronaut Office believes that the next human-rated spacecraft must include a robust full-envelope abort or escape system. The safety of the overall system depends on the reliability of both the booster and the abort or escape system. As with the rocket itself, the abort or escape system reliability must be proven through flight testing.

I. Introduction

Flying in space will always involve some measure of risk. Astronauts are willing to accept significant risks to further the cause of space exploration. Nevertheless, the Astronaut Office believes that future spacecraft can and should be much safer than present systems.

The CAIB, in its 2003 report, advised NASA to adopt flight safety as its "overriding priority." In hearings following the loss of Columbia, members of Congress agreed with that recommendation, emphasizing that improved safety is essential to maintaining NASA's credibility with both the public and Congress.

Shortly after the Columbia accident, the OSP Program released its Level 1 Requirements and Operational Concepts. These stated in part that, "The vehicle(s) shall initially launch on an [expendable launch vehicle] ELV," referring to the Atlas V and Delta IV ELVs. These rockets belong to a family of vehicles with a success rate of 0.975. Even with extensive modifications, they may never achieve a meaningfully higher success rate.[1] For comparison, the success rate of the Space Shuttle if viewed solely as a launch vehicle is 0.991 (one ascent failure in 113 flights, counting the Columbia accident as an entry failure because it achieved a safe orbit after launch).

Although history has shown that deadly accidents can occur during any phase of flight, ascent still poses a major risk to human life. If we wish to send explorers into space on increasingly ambitious missions, we must first solve the problem of putting humans into orbit more safely than is possible with our current launch systems.

The Columbia accident, the selection of a booster for the OSP, and NASA's recently renewed interest in exploring beyond low Earth orbit have led the Astronaut Office to reexamine its views on launch system safety. Although flying in space will always involve some measure of risk, it is our consensus that an order-of-magnitude reduction in the risk of loss of human life during ascent, compared to the Space Shuttle, is both achievable with current technology and consistent with NASA's focus on steadily improving rocket reliability, and should therefore represent a minimum safety benchmark for future systems.

II. Flight Safety and Reliability

Flight safety means protecting the lives of the crew as the top priority, above cost, manpower, reusability, adherence to schedule, and all other considerations, given that we are undertaking a dangerous mission and that our resources are finite.

Flight safety is not just a philosophical viewpoint. It is also a measurable quantity: the reliability of the systems upon which the crew's safety depends. But according to reliability theory,[2] it is not possible to measure a vehicle's reliability exactly. Instead, the probability of a safe flight must be estimated using mathematical models, flight history, or a combination of both.

In this paper, we define ascent as the time from crew arrival at the launch pad until insertion into an orbit that is safe for at least 24 hours, or, in cases where such an orbit is not reached, until crew recovery by rescue forces on Earth. We will use three statistical definitions of ascent reliability: predicted reliability, success rate, and demonstrated reliability.

Predicted reliability is an estimate of reliability, made in the absence of sufficient flight data, through the use of probabilistic risk assessment or other trustworthy modeling techniques. Its accuracy is limited because it relies on an incomplete understanding of the machine and its environment and usually takes into account only known failure modes. As flight data becomes available, it can be included in the models to improve the accuracy of reliability predictions.

A rocket's *success rate* is the number of times it has safely reached orbit, divided by the number of times it has been launched. For piloted missions, we count a flight reaching an incorrect but safe orbit as a success, since it does not threaten the lives of the crew even if the mission is lost. Success rate is not the same as reliability. But with enough launches the success rate will gradually become an accurate estimate of reliability.

Demonstrated reliability is an estimate of reliability based on the success rate, with allowances for statistical uncertainty.

Even a "mature" launch system with a long flight history has significant uncertainty in its reliability. To reflect that uncertainty, every reliability estimate must include a *confidence level*, which allows for the possibility that a rocket's modeled performance or existing safety record, because of analytical errors or random chance, does not reflect the truth. A standard confidence level is 95 percent, meaning that there is only a 5 percent chance that the system's real reliability is outside the bounds of the estimate.[3] A lower confidence level means a greater probability that the actual value of reliability falls outside the range of the estimate. For rockets carrying people, where low reliability is of greatest concern, a reduced confidence level corresponds to a greater likelihood of unrecognized danger.

Demonstrated reliability estimates at 95 percent confidence will be very low for new systems when the number of flights is small. This is because even an untrustworthy system can succeed a few times by random chance. It is just this kind of chance that the confidence level is intended to compensate for. (Confidence levels are less important if data from hundreds or thousands of flights is available to reduce the statistical uncertainty in the reliability estimate to an acceptably low value. Such a rich test history is characteristic of airplane programs, but not of launch systems in the past or near future.) Note that the Shuttle was declared "operational" at a time when its demonstrated reliability could only be said to be better than 0.473 with 95 percent confidence.

We now apply these concepts to the reliability of future human-rated launch systems. As we discuss below, adding abort or escape systems to a booster with an ascent reliability at least as high as the Space Shuttle's could yield a future launch system with an order-of-magnitude less ascent risk than the Shuttle. Such a system, which the Astronaut Office believes is feasible using present technology and production processes, would answer the call for meaningfully improved flight safety as called for by Congress, the CAIB,[4] and the Astronaut Office.[5] It is also consistent with the ascent risk requirement accepted by the former OSP Program. This new safety benchmark corresponds to a predicted probability of 0.999 or better for crew survival during ascent. If flown enough times, it should demonstrate the same reliability. To ensure that a new system achieves its safety requirement, it should be designed to meet or exceed that value with the standard 95 percent confidence.

The Astronaut Office recommends that the next human-rated launch system add abort or escape systems to a booster with ascent reliability at least as high as the Space Shuttle's, yielding a predicted probability of 0.999 or better for crew survival during ascent. The system should be designed to achieve or exceed its reliability requirement with 95 percent confidence.

III. Managing and Designing for Flight Safety

Designing significantly safer space vehicles requires adopting flight safety as the overarching figure of merit and implementing measures that have been shown to minimize risk, including those outlined in the CAIB Report.[4] Practices of safety-conscious flight programs include the following: Systems should be assumed to be unsafe until proven otherwise. Waivers should not be accepted without rigorous technical justification. Expert advice from outside the organization should be sought and heeded to assess program management, vehicle design, construction, test, and operations. Safety must never be compromised by cost, schedule, or other considerations. The concepts of programmatic risk (to cost and schedule) and operational risk (to life and property) must be carefully separated.

Requirements, especially safety requirements, for a human-rated launch vehicle must be specific, unambiguous, and verifiable. New programs must follow NASA's Human Rating Requirements (NPG 8705), protect those requirements from unnecessary "tailoring," weakening, and abandonment, and ensure that they are met.

Thorough, objective trade studies must be done to identify the design that best meets the requirements. Choices of technology and architecture should be guided by flight safety over cost, schedule, or any other priority.

New programs should choose conservative, simple designs, which are usually safer. They should adopt proven design standards and analytical approaches. Designs should preserve healthy margins and factors of safety, and employ redundancy in critical systems. Human rating should be designed in, not appended on. Well-understood, high-quality, high-reliability materials, components, and architectures should be selected. Hardware and software should be designed to degrade gracefully rather than fail catastrophically. The system must provide human insight into subsystems and allow human intervention during failures. Future improvements and supplementary backup systems must not be assumed to adequately substitute for a good basic design.

The Astronaut Office recommends that new human-rated launch vehicle programs follow guidelines, such as those given in the CAIB Report and NASA's Human Rating Requirements (NPG 8705), for safety-conscious management, requirements definition, concept development, and design selection.

IV. Predicted Reliability of New Designs

History has shown that rocket developers may exaggerate the merits of their systems. An early claim for the Space Shuttle's probability of crew survival was 0.99999, thousands of times safer than later demonstrated.[6] Because safety is the most important consideration for human-rated space vehicles, predicted reliability must be quantitatively understood at all stages of design.

A long record of successful flights is the best way to demonstrate flight safety. When a new system lacks enough flight history to support reliability claims, test results are the next best choice. During early development there is no hardware to test, so reliability must be predicted using state-of-the-art modeling techniques such as probabilistic risk assessment. Unfortunately, predicted reliability figures can be suspect, even if they are produced using modern, standardized techniques. The system developer owns the proprietary data upon which the models are based and these data are rarely shared for independent verification. Complex reliability models contain numerous parameters that are uncertain or subject to interpretation. (Models of this kind are notorious for being able to produce any answer the modeler wants to obtain.) Some reliability models treat only component failures, neglecting human errors in processing and operations. Finally, most reliability models treat only known modes of failure and may miss significant risks from unforeseen causes, especially unintended interactions between parts of a complex system (such as foam from the Shuttle's external tank striking the wing leading edge).

Greater confidence in predicted reliability numbers can be realized in several ways. One is to specify standard modeling methods for producing them. Another is to validate them through independent third-party verification using separately developed models. It may also be possible to truth-test reliability models against comparable existing systems with more precisely known reliability. Many models can be made more realistic by expanding them to include human errors in processing and operations as well as the possibility of unanticipated failure modes. Verification of this kind is difficult to obtain, but the powerful influence of model reliability estimates in determining the ultimate safety of the design (and hence the ultimate success of the program) demands thorough validation of the models and their results.

The Astronaut Office recommends that NASA specify and maintain a set of formal, standardized, complete methods and processes to be used in predicting the reliability of human-rated spacecraft, and identify or create an independent body to verify those analyses.

V. Verifying Flight Safety Through Testing and Operations

Once hardware is built, its reliability can be accurately assessed, first through testing and later during operations. Because testing will expose the vulnerabilities in a system more accurately and more realistically than analysis, vigorous testing to qualify all levels of the system, including individual and integrated components, on the ground and in flight is essential. Flight testing should progressively expand the envelope, following proven aviation practices. Test flights should identify the system's weakest parts and exercise them most strenuously. The flight test program must demonstrate that the system's reliability meets the requirements, either through the sheer number of tests, through proving a safe envelope much larger than expected during operations, through validation of system models, or through a combination of all three.

The formal test program for a new commercial or military airplane involves hundreds of test flights. The large number of tests yields complete, precise understanding of the hardware and its performance. Such a comprehensive test program for a new spacecraft is likely to be prohibitively expensive. It is therefore expected that the next new human-rated spacecraft will be much less well understood than the next new military airplane when it goes into operation. Accordingly, even after completion of a formal test program, the spacecraft should still be operated as though it were an experimental vehicle. Operational practices associated with this paradigm include collection, archiving, and timely analysis of data on the health and performance of all systems. All anomalies should be recorded, tracked, and aggressively investigated. Unresolved anomalies should be considered constraints to flight. The system's reliability estimates and their underlying models must be continuously refined to reflect the vehicle's actual performance. An ancillary advantage of such an operational paradigm is that it will formally identify and capture ideas that will be useful in further improving the safety of current and future launch vehicles.

The Astronaut Office recommends that the test program for the next human-rated launch system demonstrate its reliability through vigorous ground and flight testing of components and systems. The value of each test should be leveraged by proving a safe envelope larger than that expected during operations and by using flight data to validate system reliability models. After completion of the formal test program, the vigilance applied during testing to data gathering, analysis, and flight constraints should continue to be applied during operations. Reliability should be continuously reassessed.

VI. Improving Ascent Safety with Abort and Escape Systems

The current benchmark for ascent reliability is the Space Shuttle's success rate of 0.991. Existing commercial rockets have lower success rates. [1] Given the low reliability of even the safest existing rockets, meeting the Astronaut Office's goal of an order-of-magnitude reduction in the risk of space flight will require making the risk of losing the *crew* much smaller than the risk of losing the *booster*. This can be achieved by adding abort and escape systems. The "Astronaut Office Position on Crew Survivability During Ascent and Entry" [5] defines an "abort" as a failure case where the crew stays in the part of the spacecraft normally designed to carry them during entry, as with an Apollo-style tractor rocket. "Escape" means that the crew leaves the crew compartment after the failure, as with an escape pod, ejection seats, or bailout capability. A successful abort or escape is one in which the crew survives abort or escape initiation, separation from the booster, descent and landing, awaiting rescue forces, and being securely recovered by those forces. All elements involved in abort or escape flight, landing, post-landing survival, and rescue efforts are considered part of the abort or escape system. Portions of the flight trajectory where abort and escape are impossible are called "black zones." Because the overall safety of the system depends so strongly on the abort or escape system, black zones greatly increase overall flight risk. They should therefore be minimized to the fullest extent possible. The safest design will include a "full envelope" abort or escape system, which provides the crew with a secondary way to survive vehicle failures at all points in the flight profile.

Abort and escape systems must operate very quickly and precisely, may need to withstand the detonation of hundreds of tons of explosive propellants in close proximity, must perform across a wide and never fully understood range of conditions, and may drop the crew compartment onto inhospitable locations on the Earth's surface where the crew might wait days to be rescued. The reliability of an abort or escape system must include its ability to save the crew from all credible failures at all times during ascent, and its ability to protect them after separation from the rocket until recovery by rescue forces.

Abort and escape systems can never be perfectly reliable. Historically, about 13 percent of rocket accidents have involved catastrophic stack failures occurring with so little warning that notional abort or escape systems likely could not have saved a crew on board.[1] Considering the challenges of separation alone, abort or escape system reliability figures higher than about 0.87 may be difficult to achieve without specifically designing the booster to fail only in benign ways. Even if separation from the failing booster is successful, abort descents, landings, and rescue scenarios are more difficult to survive than their nominal counterparts, implying an overall abort or escape system reliability even lower than 0.87. Because of the abort or escape system's vital role in protecting the lives of the crew, its reliability estimates must be comprehensive and realistic during the design phase, and supported by rigorous flight-testing after hardware exists.

The table below shows how the rate of fatal accidents depends on the reliabilities of the booster and the abort or escape system. To clearly illustrate the effect of both parameters, we convert ordinary reliability figures (e.g., 0.999) to expected numbers of fatal accidents per 1,000 launches. Presented in this format, the Space Shuttle's 0.991 ascent success rate becomes 9 fatal accidents per 1,000 launches, and the Astronaut Office safety target of 0.999 is one fatal accident per 1,000 launches. In the table, green denotes combinations of booster and abort system reliabilities that meet that target. Systems with two or fewer fatal accidents per 1,000 launches are shown in yellow.

Table 1. Fatal ascent accidents per 1,000 launches, for different values of booster and abort or escape system reliability.

Booster Reliability	Abort or Escape System Reliability 0.800	0.850	0.900	0.950
0.995	1.0	0.75	0.5	0.25
0.990	2.0	1.5	1.0	0.5
0.980	4.0	3.0	2.0	1.0
0.970	6.0	4.5	3.0	1.5
0.960	8.0	6.0	4.0	2.0
0.950	10.0	7.5	5.0	2.5

The table shows that if the abort or escape system has a reliability of 0.900 (chosen as a reasonable upper limit, following the discussion above and presuming a booster designed not to fail catastrophically, so that the abort or escape system reliability can exceed 0.87), the Astronaut Office safety target of 1 fatal accident per 1,000 launches can be reached only by selecting a booster with a reliability of 0.990 or better. Existing commercial rockets have demonstrated reliabilities near 0.950 with 95 percent confidence.[1] The Space Shuttle, if viewed solely as a launch vehicle, has a high success rate of 0.991, but applying the standard 95 percent confidence level puts its demonstrated reliability near 0.960. A new booster design that avoids complex, fragile, and unproven technologies and architectures while embracing the more extensive testing, design margins, process control, instrumentation, operator intervention, and fault tolerance characteristic of current human-rated flight hardware might achieve or exceed 0.990 reliability with high confidence.

The Astronaut Office believes that the next human-rated spacecraft must include a robust full-envelope abort or escape system. The safety of the overall system depends on the reliability of both the booster and the abort or escape system. As with the rocket itself, the abort or escape system reliability must be proven through flight testing.

VII. Launching Humans on Atlas V and Delta IV Boosters

The possibility of using the current Atlas V and Delta IV rockets to launch a new, piloted spacecraft has led the Astronaut Office to look closely at the crew safety implications of this option.

- According to the OSP–ELV Human Flight Safety Certification Study Team Report,[1] the Atlas V and Delta IV rockets do not meet many of the NASA safety standards specified or referenced in NPG 8705, the Human Rating Requirements. Major changes needed to bring the vehicles into compliance would include at least: adding failure tolerance for critical systems, redesigning for greater structural safety factors (human-rated spacecraft use 1.4; Atlas V and Delta IV rockets use 1.25), adding fault detection and isolation functions, making the range destruct philosophy compatible with maximum crew survivability, wiring for insight and intervention by the crew and ground control, performing the detailed risk analyses needed for human rating, supplementing process controls in all phases of production, and flight testing to human rating standards.
- The Atlas V and Delta IV boosters were built to be cost-effective for their manufacturers, insurers, and customers, considering the value of the non-human payloads they were designed to carry. Although cost-effectiveness includes reliability considerations, safety is not the prime driver for satellite launches. The expense of human rating these existing rockets by adding design margins, redundancy, instrumentation, process control, command capability, and testing, might make them uneconomical for their original mission and could potentially be as costly as building a new human-rated booster.
- The reliability of Atlas V and Delta IV rockets is not precisely known because they are too new. Given insufficient flight data, one method for predicting reliability is to assume that a new system is about as reliable as a similar, existing system. The OSP–ELV Human Flight Safety Certification Study Team[1] used the flight record of Atlas, Delta, and Titan rockets developed under U.S. Government contracts and launched since 1990 to predict the reliability of the Atlas V and Delta IV. These rockets have been launched 236 times and reached safe orbits 230 times. The resulting reliability estimate is 0.950 or better with 95 percent confidence. The boosters' potentially low reliability would place excessive burden on abort mechanisms to save the crew. The abort or escape system would need a reliability near 0.980 for the complete launch system to meet the Astronaut Office crew survivability target. Proposed abort and escape systems were judged to be incapable of rescuing the crew from stack detonations occurring with little or no warning.[1] These failures occur often enough to prevent even a high-reliability abort or escape system from meeting its safety requirement.[1]
- Atlas V and Delta IV boosters fly to orbit on highly lofted trajectories because of second-stage performance limitations and range destruct line-of-sight requirements. If a piloted spacecraft had to abort near the apex of such a trajectory, it would hit the atmosphere at a high speed and a steep angle. The resulting heat and acceleration loads on the crew compartment would be severe and possibly not survivable.[7]

In summary, the Atlas V and Delta IV rockets should be measured against a set of concrete, specific, verifiable requirements for carrying humans before being selected for that purpose. A safer launch option might be identified by objectively comparing the advantages and drawbacks of a range of existing, modified, and new launch systems relative to those requirements.

VIII. Summary and Conclusion

If we wish to send explorers into space on increasingly ambitious missions, we must first solve the problem of getting humans into orbit more safely than is possible with our current launch systems.

The Astronaut Office believes that an order-of-magnitude reduction in the risk of loss of human life during ascent, compared to the Space Shuttle, is both achievable with current technology and consistent with NASA's focus on steadily improving rocket reliability, and should therefore represent a minimum safety benchmark for future systems. This corresponds to a predicted ascent reliability of at least 0.999. To ensure that a new system will achieve or surpass its safety requirement, it should be designed and tested to do so with a statistical confidence level of 95 percent.

Tough safety requirements can be met in part by adopting the best practices for the management, design, test, and operation of risky technology as given in the

CAIB Report, in NASA's Human Rating Requirements (NPG 8705), and in commercial and military aviation.

The burden of proving that a vehicle is safe falls on the mathematical models, tests, and operational history that measure the system's reliability. Accordingly, the Astronaut Office recommends that NASA specify and maintain a set of formal, standardized methods and processes to be used in predicting the reliability of human-rated spacecraft, and identify or create an independent body to verify those analyses. We further recommend that the test program for the next human-rated launch system demonstrate its reliability through vigorous ground and flight testing of components and systems. The value of each test should be leveraged by proving a safe envelope larger than that expected during operations and by using flight data to validate system reliability models. After completion of the formal test program, the vigilance applied during testing to data gathering, analysis, and flight constraints should continue to be applied during operations. Reliability should be continuously reassessed.

The Astronaut Office believes that the next human-rated spacecraft must include a robust full-envelope abort or escape system. The reliability of both the rocket and the abort or escape system are limited and must be proven through flight-testing.

It is our hope that NASA will adopt the principles outlined in this paper to design, build, test, and fly a new vehicle that is much safer than its existing counterparts. Such a vehicle will help ensure that our nation retains the capability for human access to space.

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[4] Gehman, H.W. et al. Columbia Accident Investigation Board Report, 2003.

[5] Astronaut Office Position on Crew Survivability During Ascent and Entry. Astronaut Office memo number CB 03–070, 2003.

[6] Feynman, R.P., Personal observations on the reliability of the Shuttle. Report of the Presidential Commission on the Space Shuttle Challenger Accident, Volume II, Appendix F, 1986.

[7] Orbital Space Plane RAC 2.02a Final Report (2003).

ATTACHMENT 2

Executive Summary from SAICNY05–04–1F, "Reliability and Crew Safety Assessment for Solid Rocket Booster/J–2S Based Launch Vehicle," Joseph R. Fragola, Blake Putney, Joseph Minarick III, Joseph D. Baum, Benjamin Franzini, Orlando Soto, Rainald Löhner, Eric Mestreau, Richard Ferricane, 1 April 2005.

NASA's Exploration Mission Directorate is currently developing plans to carry out the President's Vision for Space Exploration. This plan includes retiring the Space Shuttle by 2010 and developing the Crew Exploration Vehicle (CEV) to transport astronauts to/from Low Earth Orbit (LEO). There are several alternatives to launch the CEV, including Evolved Expendable Launch Vehicles (EELVs) and launch vehicles derived from new and existing propulsion elements. In May 2003, the astronaut office made clear its position on the need and feasibility of improving crew safety for future NASA manned missions indicating their "*consensus that an order of magnitude reduction in the risk of human life during ascent, compared to the Space Shuttle, is both achievable with current technology and consistent with NASA's focus on steadily improving rocket reliability*." The astronaut office set a goal for the Probability of Loss of Crew (PLOC) to be better than 1 in 1,000. Thus, the challenge becomes finding a launch vehicle that meets the CEV launch performance requirements while satisfying the astronaut office crew survivability requirement.

The simplest designs of the EELVs, which offer the greatest potential for inherent reliability, are the single core variants. These single core EELVs with an effective crew escape system should provide the greatest crew safety. Unfortunately, the single core EELVs are unable to meet the performance needs for the CEV mission, so the higher performance, more complex, less reliable multi-core "heavy" variants are required making it difficult to achieve the ascent risk goal proposed by the astronaut office for PLOC to be better than 1 in 1,000. This dilemma motivated the search for a launch vehicle that could preserve the simplicity of a single core propulsion system that utilizes highly reliable human rated heritage components with sufficient performance to meet the CEV mission needs. The result of this effort is a

2-stage launch vehicle utilizing a single Space Shuttle Solid Rocket Booster (SRB) for the first stage, and a single J–2S engine for the second stage.

In order to effectively evaluate the reliability and human rating aspects of all of the various launch vehicle alternatives, a 13 step "top-down scenario based risk assessment" methodology was developed. This approach is based on a phenomenological and engineering based analysis, which is subsequently used to guide a thorough Probabilistic Risk Assessment (PRA). This report documents the results of an evaluation conducted by SAIC on the SRB/J–2S based launch vehicle concept for launching the CEV based on this methodology.

The SAIC evaluation has determined that the SRB/J–2S derived launch vehicle forecasted crew safety level, as measured in missions where the crew is lost in a total number of missions, is 1 in 3,145 at the mean of the estimated uncertainty distribution with associated uncertainty bounds of 1 in 11,500 at the 5th percentile, 1 in 1,287 at the 95th percentile, and 1 in 3,861 at the median or 50th percentile. This forecast is based on the conservative assumption that all catastrophic failures of the Space Shuttle SRB are non survivable which analysis indicates is not the case.

The SRB/J–2S derived launch vehicle is forecasted to achieve this significant crew safety performance due to the following features:

1. Simple Inherently Safe Design—A single human-rated SRB first stage matured through years of experience with over 176 flights of the current design for launching crew, combined with a simple J–2S single engine upper stage evolved from the highly successful J–2 engine system used on both the second and third stages of the Saturn V. These stages have been combined in an inline configuration with the suggested Apollo Command Module based CEV and Launch Escape System (LES) so as to benefit from the natural safety distance advantages and broad escape corridors provided inherently by the inline design.

2. Design Robustness—Historical test results and 1st principles physics based simulation show that the SRB/J–2S launch vehicle design is robust, that is, resistant to crew adverse catastrophic failure, even for the most severe failure modes.

3. Historically Low Rates of Failure—In the Space Shuttle system only the 51–L event (a non-catastrophic failure of the SRB) has marred a perfect record in 226 SRBs, with 176 consecutive successful uses of the redesigned SRBs. This 1 in 226 history, or 0.996 launch success rate is perhaps the best of the best in launcher history. The J–2S, which completed 273 test firings and accumulated 30,858 seconds of run time, was developed to be simpler to produce and operate than the J–2 engine system which it derives its heritage. The flight proven J–2 engine had a significant success record, including a flawless performance from a crew safety perspective.

4. Non-Catastrophic Failure Mode Propensity—Solid rocket booster history, and specific design features of the SRB suggest a propensity for gradual thrust augmentation failures which present less of a challenge for crew survival in the inline configuration, should they occur.

5. Process Control—The proposed design offers the benefits of using propulsion suppliers with mature in-plant process control systems to minimize human error, which has proven to be a significant contributor to risk.

6. Failure Precursor Identification and Correction—The design capitalizes on the significant failure precursor identification and elimination benefit from recovery, and post flight inspection of the recovered SRBs.

It is a combination of these six factors, and not any one alone, which suggest a launch vehicle design that is forecasted to produce the significant crew safety performance as assessed by this analysis.

Senator HUTCHISON. And Mr. Allen Li is Director of Acquisition and Sourcing Management of the U.S. Government Accountability Office, GAO.

STATEMENT OF ALLEN LI, DIRECTOR, ACQUISITION AND SOURCING MANAGEMENT, U.S. GOVERNMENT ACCOUNTABILITY OFFICE

Mr. LI. Madame Chairman, Senator Nelson, Members of the Subcommittee. As requested, I will focus my brief remarks on whether

NASA is positioning itself to have people with the proper skills to maintain and operate the Shuttle safely until the very last flight. And building on Senator Hutchison's remarks on lessons learned, I will also offer some observations on NASA's plans to develop a new manned spacecraft.

Over the last 2 years NASA and its contractors have worked diligently to return the Shuttle to flight. Understandably, focus has been on STS–114. However, as we approach the day when Discovery does return to space, as we all hope it will, NASA will need to pay more attention to activities aimed an ensuring that its Shuttle workforce has the critical skills needed until the Shuttle is retired. It is this workforce that is enabling NASA to soon achieve Return to Flight. It is also the workforce that will allow NASA to finish the Space Station.

In summary, we found in our March 2005 report that NASA had made limited progress in planning efforts for sustaining the Shuttle workforce through the program's retirement. The Shuttle program has taken preliminary steps, including identifying lessons learned from the retirement of comparable programs, such as the Air Force's Titan 4 rocket program. And NASA's prime contractor for Shuttle operations, United Space Alliance, has also taken some initial steps to prepare for the impact of the Shuttle's retirement on its own workforce.

However, USA's progress depends on NASA's decisions that affect contractor requirements through the remainder of the program. So in essence, it is waiting on NASA.

In our report we identified several factors that have hampered the Shuttle program's planning efforts. For example, because of the program's near-term focus on returning the Shuttle to flight, other efforts that will ultimately aid in determining workforce requirements have been delayed. In addition, program officials indicated they faced uncertainties regarding the implementation of future aspects of the President's vision for space exploration.

I will end my remarks with two observations on current plans to develop the Crew Exploration Vehicle, otherwise known as the CEV. When the Shuttle was initially designed, ease and maintainability was not a major factor. But it should have been. A few years ago, I appeared before this Subcommittee when it reviewed the reasons behind wiring failures in the Orbiter. As it turns out, some wires, which are bundled, cracked from maintenance personnel repeatedly stepping on them to access other parts of the Orbiter. So it seems appropriate for NASA to remember this lesson and that future reusable spacecraft be designed with maintenance in mind.

Furthermore, even if the spacecraft is not totally reusable, producibility will be a factor to consider. This is important if the CEV is to be the building block for the future and is produced in different forms over 20 years. It would appear that NASA would have much to gain by insisting on designs that can be efficiently produced and thus reduce long-term costs.

This ends my verbal statement.

Senator HUTCHISON. Thank you very much.

[The prepared statement of Mr. Li follows:]

PREPARED STATEMENT OF ALLEN LI, DIRECTOR, ACQUISITION AND SOURCING MANAGEMENT, U.S. GOVERNMENT ACCOUNTABILITY OFFICE

Madam Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss how the National Aeronautics and Space Administration (NASA) is positioning itself to sustain the critically skilled Space Shuttle workforce through the retirement of the Space Shuttle program. NASA is in the midst of one of the most challenging periods in its history. It must demonstrate that the Space Shuttle can safely fly again, begin the process of retiring its largest program, and at the same time prepare for the uncertain future of space exploration. These challenges are further exacerbated by the complex task of maintaining the right workforce to support the Space Shuttle program while ensuring that the skills needed for future programs are not lost. Over the next several years, thousands of NASA civil service and contractor employees who support the Space Shuttle program will be impacted by decisions made about the remaining life of the program and implementation of exploration goals. These include decisions about the final number of Space Shuttle flights and about future programs, such as the Crew Exploration Vehicle (CEV). As requested, my testimony today will discuss the actions that NASA is taking to position itself to sustain its critically skilled Space Shuttle workforce and the challenges that the agency faces in doing so—issues we reported on to Senators Inouye and McCain in March 2005. [1]

In summary, we found that NASA had made limited progress in its planning efforts for sustaining the Space Shuttle workforce through the program's retirement. At the time of our March 2005 report, the Space Shuttle program had taken preliminary steps, including identifying the lessons learned from the retirement of comparable programs, such as the Air Force Titan IV Rocket Program. Further NASA's prime contractor for Space Shuttle operations—United Space Alliance (USA)—had taken some initial steps to prepare for the impact of the Space Shuttle's retirement on its own workforce. However, its progress depends on NASA making decisions that impact contractor requirements through the remainder of the program. Timely action to address workforce issues, however, is critical given the potential impact that they could have on NASA-wide goals. Unaddressed, such issues would likely lead to schedule delays and overstretched funding for both the Space Shuttle program and the agency. Both NASA and USA have acknowledged that sustaining their workforces will be difficult as the Space Shuttle nears retirement, particularly if a career path beyond the Space Shuttle's retirement is not apparent to their employees. In addition, the Federal Government is facing fiscal challenges. Such challenges call into question whether funding for tools, such as retention bonuses, will be available for the agency to use to aid in retaining the Space Shuttle workforce.

In our report we identified several factors that have hampered the Space Shuttle program's planning efforts. For example, because of the program's near-term focus on returning the Space Shuttle to flight, other efforts that will ultimately aid in determining workforce requirements, such as assessing hardware and facility needs, are being delayed. In addition, program officials indicated that they face uncertainties regarding the implementation of future aspects of the President's vision for space exploration (Vision) and have yet to define requirements on which workforce planning efforts would be based. Despite these factors, our prior work on strategic workforce planning has shown that, even when faced with uncertainty, successful organizations take steps, such as scenario planning, to better position themselves to meet future workforce requirements.

In our March 2005 report, we recommended that the agency begin identifying the Space Shuttle program's future workforce needs based upon various future scenarios the program could face. The program can use the information provided by scenario planning to develop strategies for meeting the needs of its potential future scenarios. NASA concurred with our recommendation, and NASA's Assistant Associate Administrator for the Space Shuttle program is leading an effort to address the recommendation. Since we issued our report and made our recommendation, NASA has taken action and publicly recognized, through its Integrated Space Operations Summit, that human capital management and critical skills retention will be a major challenge for the agency as it progresses toward retirement of the Space Shuttle.

Background

On January 14, 2004, the President articulated a new vision for space exploration for NASA. Part of the Vision includes the goal of retiring the Space Shuttle following completion of the International Space Station (ISS), planned for the end of

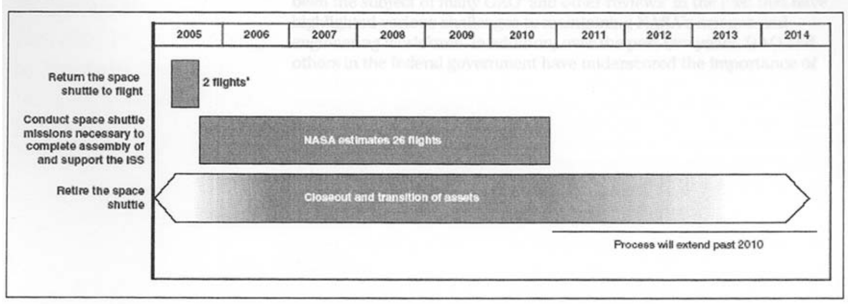
[1] GAO, *Space Shuttle: Actions Needed to Better Position NASA to Sustain Its Workforce through Retirement,* GAO–05–230 (Washington, DC: March 9, 2005).

the decade. In addition, NASA plans to begin developing a new manned exploration vehicle, or CEV, to replace the Space Shuttle and return humans to the moon as early as 2015, but no later than 2020, in preparation for more ambitious future missions. As this Subcommittee is aware, NASA's Administrator has recently expressed his desire to accelerate the CEV development to eliminate the gap between the end of the Space Shuttle program, currently scheduled for 2010, and the first manned operational flight of the CEV, currently scheduled for 2014. If the CEV development cannot be accelerated, NASA will not be able to launch astronauts into space for several years and will likely have to rely on Russia for transportation to and from the ISS. A 1996 "Balance Agreement" between NASA and the Russian space agency, obligated Russia to provide 11 Soyuz spacecraft for crew rotation of U.S. and Russia crews. After April 2006, this agreement will be fulfilled and Russia no longer must allocate any of the seats on its Soyuzes for U.S. astronauts. Russian officials have indicated that they will no longer provide crew return services to NASA at no cost at that time. However, NASA may face challenges to compensating Russia for seats on its Soyuzes after the agreement is fulfilled due to restrictions in the Iran Nonproliferation Act.[2]

The Space Shuttle, NASA's largest individual program,[3] is an essential element of NASA's ability to implement the Vision because it is the only launch system presently capable of transporting the remaining components necessary to complete assembly of the ISS. NASA projects that it will need to conduct an estimated 28 flights over the next 5 to 6 years to complete assembly of and provide logistical support to the ISS. However, NASA is currently examining alternative ISS configurations to meet the goals of the Vision and satisfy NASA's international partners, while requiring as few Space Shuttle flights as possible to complete assembly.

Prior to retiring the Space Shuttle, NASA will need to first return the Space Shuttle safely to flight[4] and execute whatever number of remaining missions are needed to complete assembly of and provide support for the ISS. At the same time, NASA will begin the process of closing out or transitioning its Space Shuttle assets that are no longer needed to support the program—such as its workforce, hardware, and facilities—to other NASA programs. The process of closing out or transitioning the program's assets will extend well beyond the Space Shuttle's final flight (see fig. 1).

Figure 1: Estimated Timeline for the Process of Retiring NASA's Space Shuttle



Source: NASA; GAO (presentation).

*The planning window for the first flight is July 13 through July 31, 2005.

Retiring the Space Shuttle and, in the larger context, implementing the Vision, will require that the Space Shuttle program rely on its most important asset—its

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[2] The Iran Nonproliferation Act (Pub. L. 106–178). The Iran Nonproliferation Act bans the United States from making extraordinary payments to Russia in connection with the International Space Station, unless the President determines, among other things, that Russia demonstrated a commitment to prevent the transfer to Iran of goods, services, and technology that could materially contribute to developing nuclear, biological, or chemical weapons, or of ballistic or cruise missile systems.

[3] The Space Shuttle program accounted for 27 percent of NASA's Fiscal Year 2005 budget request.

[4] To return the Space Shuttle to flight, NASA will conduct two flights, which are intended to test and evaluate new procedures for flight safety implemented as a result of the Space Shuttle Columbia accident. The planning window for the first flight is July 13 through July 31, 2005.

workforce. The Space Shuttle workforce consists of about 2,000 civil service [5] and 15,600 contractor [6] personnel, including a large number of engineers and scientists. While each of the NASA centers support the Space Shuttle program to some degree, the vast majority of this workforce is located at three of NASA's Space Operations Centers: Johnson Space Center, Kennedy Space Center, and Marshall Space Flight Center. Data provided by NASA shows that approximately one quarter of the workforce at its Space Operations centers is 51 years or older and about 33 percent will be eligible for retirement by Fiscal Year 2012. [7]

The Space Shuttle workforce and NASA's human capital management have been the subject of many GAO [8] and other reviews [9] in the past that have highlighted various challenges to maintaining NASA's science and engineering workforce. In addition, over the past few years, GAO and others in the Federal Government have underscored the importance of human capital management and strategic workforce planning. [10] In response to an increased governmentwide focus on strategic human capital management, NASA has taken several steps to improve its human capital management. These include steps such as devising an agencywide strategic human capital plan, developing workforce analysis tools to assist in identifying critical skills needs, and requesting and receiving additional human capital flexibilities. [11]

Progress Toward Developing a Strategy To Sustain the Space Shuttle Workforce is Limited

NASA has made only limited progress toward developing a detailed longterm strategy for sustaining its workforce through the Space Shuttle's retirement. While NASA recognizes the importance of having in place a strategy for sustaining a critically skilled workforce to support Space Shuttle operations, it has only taken preliminary steps to do so. For example, the program identified lessons-learned from the retirement of programs comparable to the Space Shuttle, such as the Air Force Titan IV Rocket Program. Among other things, the lessons learned reports highlight the practices used by other programs when making personnel decisions, such as the importance of developing transition strategies and early retention planning.

Other efforts have been initiated or are planned; examples include the following:

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[5] Number is based on a full-time equivalent calculation. Full-time equivalent is a measure of staff hours equal to those of an employee who works 40 hours per week in 1 year; therefore, the actual number of employees who work part-time or full-time on the Shuttle Program is greater than 2,000. The number was calculated by averaging the number of civil service employees over Fiscal Year 2004.

[6] The number was calculated by averaging the number of contractor employees over Fiscal Year 2004. This number includes data from NASA's prime contractor for Space Shuttle operations, United Space Alliance, and other NASA contractors. United Space Alliance, established in 1996 as a joint venture between Lockheed Martin and Boeing to consolidate NASA's various Space Shuttle program contracts under a single entity, and its approximately 10,400 employees are responsible for conducting the Space Shuttle's ground and flight operations under the Space Flight Operations Contract. The remaining contractor personnel are associated with other Space Shuttle components, such as its propulsion systems.

[7] Data provided by NASA is as of September 30, 2004. GAO did not perform a reliability assessment of the data.

[8] GAO, *Space Shuttle: Human Capital Challenges Require Management Attention,* GAO/T-NSIAD–00–133 (Washington, DC: Mar. 22, 2000) and GAO, *Space Shuttle: Human Capital and Safety Upgrade Challenges Require Continued Attention,* GAO/NSIAD/GGD–00–186 (Washington, DC: August 15, 2000).

[9] *Columbia Accident Investigation Board, Report Volume I* (Washington, DC: August 2003); Aerospace Safety Advisory Panel, *Annual Report for* 2001 (Washington, DC: March 2002); Behavioral Sciences Technology, Inc., *Assessment and Plan for Organizational Culture Change at NASA* (Ojai, California: March 15, 2004).

[10] GAO, *High-Risk Series: An Update,* GAO–01–263 (Washington, DC: January 2001); GAO, *High-Risk Series: An Update,* GAO–03–119 (Washington, DC: January 2003); GAO, *High-Risk Series: An Update,* GAO–05–207 (Washington, DC: January 2005); GAO, *Performance Accountability Series—Major Management Challenges and Program Risks: A Governmentwide Perspective,* GAO–01–241 (Washington, DC: January 2001); GAO, *Major Management Challenges and Program Risks: A Governmentwide Perspective,* GAO–03–95 (Washington, DC: January 2003); GAO, *Major Management Challenges and Program Risks: National Aeronautics and Space Administration,* GAO–01–258 (Washington, DC: January 2001); and GAO, *Major Management Challenges and Program Risks: National Aeronautics and Space Administration,* GAO–03–114 (Washington, DC: January 2003); GAO, *Human Capital: Key Principles for Effective Strategic Workforce Planning,* GAO–04–39 (Washington, DC: December 11, 2003); GAO, *A Model of Strategic Human Capital Management,* GAO–02–373SP (Washington, DC: March 15, 2002); and GAO, *Human Capital: A Self-Assessment Checklist for Agency Leaders,* GAO/OCG–00–14G (Washington, DC: September 1, 2000). See also www.gao.gov/pas/2005.

[11] Enacted in February 2004, the NASA Flexibility Act of 2004 (Pub. L. 108–201) amends title 5, United States Code, by inserting a new chapter 98 in that title, which provides new authorities to NASA. On March 26, 2004, NASA submitted a written workforce plan for using its new authorities to Congress.

- contracted with the National Academy of Public Administration to assist it in planning for the Space Shuttle's retirement and transitioning to future programs; and
- began devising an acquisition strategy for updating propulsion system prime contracts at MSFC to take into account the Vision's goal of retiring the Space Shuttle following completion of the ISS.

NASA's prime contractor for Space Shuttle operations, USA, has also taken some preliminary steps, but its progress with these efforts depends on NASA making decisions that impact contractor requirements through the remainder of the program. For example, USA has begun to define its critical skills needs to continue supporting the Space Shuttle program, devised a communication plan, contracted with a human capital consulting firm to conduct a comprehensive study of its workforce; and continued to monitor indicators of employee morale and workforce stability. Contractor officials said that further efforts to prepare for the Space Shuttle's retirement and its impact on their workforce are on hold until NASA first makes decisions that impact the Space Shuttle's remaining number of flights and thus the time frames for retiring the program and transitioning its assets.

The Potential Impact of Workforce Problems and Other Challenges the Space Shuttle Program Faces Highlight the Need for Workforce Planning

Making progress toward developing a detailed strategy for sustaining a critically skilled Space Shuttle workforce through the program's retirement is important given the impact that workforce problems could have on NASA-wide goals. According to NASA officials, if the Space Shuttle program faces difficulties in sustaining the necessary workforce, NASA-wide goals, such as implementing the Vision and proceeding with space exploration activities, could be impacted. For example, workforce problems could lead to a delay in flight certification for the Space Shuttle, which could result in a delay to the program's overall flight schedule, thus compromising the goal of completing assembly of the ISS by 2010. In addition, officials said that space exploration activities could slip as much as 1 year for each year that the Space Shuttle's operations are extended because NASA's progress with these activities relies on funding and assets that are expected to be transferred from the Space Shuttle program to other NASA programs.

NASA officials told us they expect to face various challenges in sustaining the critically skilled Space Shuttle workforce. These challenges include the following:

- *Retaining the current workforce*. Because many in the current workforce will want to participate in or will be needed to support future phases of implementing the Vision, it may be difficult to retain them in the Space Shuttle program. In addition, it may be difficult to provide certain employees with a transition path from the Space Shuttle program to future programs following retirement.
- *Impact on the prime contractor for Space Shuttle operations*. Because USA was established specifically to perform ground and flight operations for the Space Shuttle program, its future following the Space Shuttle's retirement is uncertain. Contractor officials stated that a lack of long-term job security would cause difficulties in recruiting and retaining employees to continue supporting the Space Shuttle as it nears retirement. In addition, steps that the contractor may have to take to retain its workforce, such as paying retention bonuses, are likely to require funding above normal levels.
- *Governmentwide budgetary constraints*. Throughout the process of retiring the Space Shuttle, NASA, like other federal agencies, will have to contend with urgent challenges facing the federal budget that will put pressure on discretionary spending—such as investments in space programs—and require NASA to do more with fewer resources.

Several Factors Have Impeded Workforce Planning Efforts

While the Space Shuttle program is still in the early stages of planning for the program's retirement, its development of a detailed long-term strategy to sustain its future workforce is being hampered by several factors:

- *Near-term focus on returning the Space Shuttle to flight*. Since the Space Shuttle Columbia accident, the program has been focused on its near-term goal of returning the Space Shuttle safely to flight. While this focus is understandable given the importance of the Space Shuttle's role in completing assembly of the ISS, it has led to the delay of efforts to determine future workforce needs.

- *Uncertainties with respect to implementing the Vision*. While the Vision has provided the Space Shuttle program with the goal of retiring the program by 2010 upon completion of the ISS, the program lacks well-defined objectives or goals on which to base its workforce planning efforts. For example, NASA has not yet determined the final configuration of the ISS, the final number of flights for the Space Shuttle, how ISS operations will be supported after the Space Shuttle is retired, or the type of vehicle that will be used for space exploration. These determinations are important because they impact decisions about the transition of Space Shuttle assets. Lacking this information, NASA officials have said that their ability to progress with detailed long-term workforce planning is limited.

Despite Uncertainties, NASA Could Follow a Strategic Human Capital Management Approach

Despite these uncertainties, the Space Shuttle program could follow a strategic human capital management approach to plan for sustaining its critically skilled workforce. Studies by several organizations, including GAO, have shown that successful organizations in both the public and private sectors follow a strategic human capital management approach, even when faced with an uncertain future environment.

In our March 2005 report, we made recommendations aimed at better positioning NASA to sustain a critically skilled Space Shuttle workforce through retirement. In particular, we recommended that the agency begin identifying the Space Shuttle program's future workforce needs based upon various future scenarios the program could face. Scenario planning can allow the agency to progress with workforce planning, even when faced with uncertainties such as those surrounding the final number of Space Shuttle flights, the final configuration of the ISS and the vehicle that will be developed for exploration. The program can use the information provided by scenario planning to develop strategies for meeting the needs of its potential future scenarios. NASA concurred with our recommendation, and NASA's Assistant Associate Administrator for the Space Shuttle program is leading an effort to address the recommendation.

Since we issued our report and made our recommendation, NASA has taken action and publicly recognized that human capital management and critical skills retention will be a major challenge for the agency as it moves toward retiring the Space Shuttle. This recognition was most apparent at NASA's Integrated Space Operations Summit held in March 2005. As part of the Summit process, NASA instituted panel teams to examine the Space Shuttle program's mission execution and transition needs from various perspectives and make recommendations aimed at ensuring that the program will execute its remaining missions safely as it transitions to supporting emerging exploration mission needs. The reports that resulted from these examinations are closely linked by a common theme—the importance of human capital management and critical skills retention to ensure success. In their reports, the panel teams highlighted similar challenges to those that we highlighted in our report. The panels made various recommendations to the Space Flight Leadership Council on steps that the program should take now to address human capital concerns. These recommendations included developing and implementing a critical skills retention plan, developing a communication plan to ensure the workforce is informed, and developing a detailed budget that includes funding for human capital retention and reductions, as well as establishing an agencywide team to integrate human capital planning efforts.

Conclusions

There is no question that NASA faces a challenging time ahead. Key decisions have to be made regarding final configuration and support of the ISS, the number of shuttle flights needed for those tasks, and the timing for development of future programs, such as the CEV—all in a constrained funding environment. In addition, any schedule slip in the completion of the construction of the ISS or in the CEV falling short of its accelerated initial availability (as soon as possible after Space Shuttle retirement) may extend the time the Space Shuttle is needed. But whatever decisions are made and courses of action taken, the need for sustaining a critically skilled workforce is paramount to the success of these programs. Despite a limited focus on human capital management in the past, NASA now acknowledges that it faces significant challenges in sustaining a critically skilled workforce and has taken steps to address these issues. We are encouraged by these actions and the fact that human capital management and critical skills retention was given such prominent attention throughout the recent Integrated Space Operations Summit process. The fact that our findings and conclusions were echoed by the panel teams established to support the Integrated Space Operations Summit is a persuasive reason for

NASA leadership to begin addressing these human capital issues early and aggressively.

Madam Chairman, this concludes my prepared statement. I would be pleased to respond to any questions that you or other Members of the Subcommittee may have.

Senator HUTCHISON. Dr. Freese, I would like for you to go back and expand a little bit on the concerns that you have from a national security standpoint about the United States having the independent ability to launch and support humans in space.

Dr. JOHNSON-FREESE. Space has always had a very strong symbolic value. Today we term that techno-nationalism. That is—science and technology is an indicator of national power. And with space representing the future, any slippage in U.S. leadership in human spaceflight capability translates into a negative indicator of national power.

Countries are acutely aware of that. And specifically, China is reaping great rewards in techno-nationalism right now from its very incremental and very spartan, but very ambitious, human spaceflight program. That creates a perception of competition, where the Chinese only have to be consistent and we have to—we are put in a position where we are racing against ourselves to outdo our past, our glorious space past. And I think this puts us in a very precarious position.

Senator HUTCHISON. Is there anything quantifiable about what we would lose if we could not put humans into space within a 5-year period, other than perception of power loss?

Dr. JOHNSON-FREESE. Well, again, perception is soft power. And while that is very hard to quantify, it is very real. There are some fields, certainly there is medical research and there are certain fields, life support research, that have to do with human space flight which has technology benefits that we would lose in. But my work primarily focuses on the soft power issues, which I think are considerable.

Senator HUTCHISON. Mr. Li, let me just ask you: What do you think are the highest risk workforce retention issues that you see as we get toward 2010, while also trying to get the Crew Return Vehicle online?

Mr. LI. Thank you for that question. I think at issue here is if we do not have a plan that is fully understood by the workforce, they will migrate toward what is best for them. And that unknown may be not knowing what the program, future program, will be. And they might in essence leave the Shuttle workforce, which would be very bad, obviously in terms of safety.

Senator HUTCHISON. Senator Nelson?

Senator NELSON. Mr. McCulley, you are experiencing that right now, are you not, with some of your young engineers?

Mr. MCCULLEY. Yes, sir, I am. And one quick anecdotal story. I have a young man from Pennsylvania who came out of college and moved to Florida specifically to work on our nations space programs and in particular, human spaceflight programs. Last week in the cafeteria at the Kennedy Space Center he said, “Mike, what about my future? I’ve got two children now and a wife. And there’s jobs in Pennsylvania that I’m aware of. And I’m debating whether or not I should take it.” And he is in a very serious internal debate with his family.

Now I will tell you that at this point we have no problem at all in recruiting, which has been very, very pleasing, given the accident. We are having no problems at all getting good people. I do not think we will have any problem for the next year or two. But my folks are starting to think about, what do I do post-Shuttle until we get a more definition? And I applaud Dr. Griffin's efforts to get that definition sooner rather than later.

Senator NELSON. Dr. Freese, in our world of politics perception is not only soft power, it is hard power. But thank you for telling us about what perception means to the world with regard to the United States space program. Taking that a step further, what happens to our perception if our partners, our international partners up there on the Space Station either are there because it has been completed or not there because it has not been completed, and it comes 2010 and there is no Space Shuttle to service and build the Space Station?

Dr. JOHNSON-FREESE. That is a scenario that I do not think would be in our best interest. I strongly believe we need to be coopting others to work with us inclusively so that we can avoid a situation where the United States is the odd man out potentially on the Space Station. And that could occur.

Senator NELSON. Dr. Horowitz, what are the advantages to using Space Shuttle-derived systems for helping implement this CEV?

Dr. HOROWITZ. Thank you, Senator. Well, as everyone else, we are very concerned about the gap. And the best way to avoid the gap is to take the equipment that we already have at our disposal—I mean, we already have the solid rocket booster first stage of the vehicle that I described. It is already built and flying today. So we can minimize the amount of development time, and the cost. And then we can meet the ambitious schedule of having a Crew Exploration Vehicle ready to fly in 2010, because we have most of the propulsion components already. They are already human-rated. And it will be safer and more effective than anything else we could do.

Senator NELSON. And of course, that will be something that NASA will be looking at——

Dr. HOROWITZ. Yes, sir.

Senator NELSON.—trying to make that decision, what is best safety-wise, as well as from a cost and timing schedule.

Thank you, Madame Chairman. This has been an excellent, excellent hearing. And you have compressed it into 35 minutes. It is a record, Madame Chairman.

Senator HUTCHISON. Well, thank you. It took the cooperation of everyone involved. And let me just make one last quick statement. And that is that I do believe that NASA is looking at and will be working with you, Mr. McCulley, to use many of the people who are also doing the Space Shuttle for the Crew Return Vehicle evolution. So I do not think the picture is totally bleak here. I think there will be a lot of overlap that will help to keep our best people. And I know that between you and Dr. Griffin and all of the people in your two organizations that you will work hard to coordinate that.

I want to remind everyone that all the statements and additional materials from the witnesses will be made a part of the hearing record, and also any answers that you might have to questions that might not have been asked but will be submitted to you in writing by members will also be made a part of the record.

Thank you for the cooperation on this very short time frame. We appreciate it. We have learned a lot in a short time, and we appreciate your cooperation.

Thank you.

[Whereupon, at 11:35 a.m., the hearing was adjourned.]

A P P E N D I X

PREPARED STATEMENT OF HON. DANIEL K. INOUYE, U.S. SENATOR FROM HAWAII

First, I would like to welcome Administrator Griffin back to the Commerce Committee. Last month, you came before us as the nominee to head NASA, and now you are back to have a discussion on one of your most difficult challenges, moving human spaceflight out of the Shuttle era.

Of course before we do that, NASA needs to return the Shuttle safely to flight. You've done a lot of work since February 2003, and we will all be rooting for you in July. It is my hope that you've really started to fix what the Columbia Accident Investigation Board called the "cultural problems."

Administrator Griffin, I commend you on delaying the next flight from May until July so that you could satisfy yourself of its safety.

The Committee will also be watching closely as you continue to refine the plans for our next generation space transportation system. We all agree. A 4-year or longer gap in the United States' ability to fly humans into space is unacceptable. We need a safe, robust, capable crew exploration vehicle and the cargo and lift systems to support it. I hope that you will help us understand the tradeoffs that will need to be made to get that system sooner rather than later.

Of course, as we look to the future, we cannot abandon the past. The Space Shuttle will need to meet an aggressive schedule over the next 5 years. We need to complete the Space Station and to use the lab we have built. We should not abandon the important science NASA does, whether it is the Hubble Space telescope, Earth science, or aeronautics. I look forward to working with you and the Members of the Committee to ensure NASA can keep reaching for the stars.

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