NATIONAL IMPERATIVES FOR EARTH AND CLIMATE SCIENCE RESEARCH AND APPLICATIONS INVESTMENTS OVER THE NEXT DECADE

HEARING

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

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February 13, 2007

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NATIONAL IMPERATIVES FOR EARTH AND CLIMATE SCIENCE RESEARCH AND APPLICATIONS INVESTMENTS OVER THE NEXT DECADE

TUESDAY, FEBRUARY 13, 2007

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Committee met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bart Gordon [Chairman of the Committee] presiding.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

National Imperatives for Earth and Climate Science Research and Applications Investments over the Next Decade

February 13, 2007
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

Dr. Richard Anthes
President
University Corporation for Atmospheric Research

Dr. Berrien Moore III
Director
Institute for the Study of Earth, Oceans, and Space
University of New Hampshire

Hon. James Geringer
Director of Policy
Environmental Systems Research Institute

HEARING CHARTER

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

National Imperatives for Earth and Climate Science Research and Applications Investments Over the Next Decade

TUESDAY, FEBRUARY 13, 2007
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On February 13, 2007 the Committee on Science and Technology will hold a hearing to examine the findings and recommendations of the National Academies report *"Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond,"* also known as the Decadal Survey. The report recommends a prioritized set of investments in new satellite-borne instruments and spacecraft to gather Earth, atmospheric, and climate data. These new satellites would replace our aging space-based observing system to support national needs for research and monitoring of the dynamic Earth system during the next decade, as well as identifying important research and applications directions that should influence planning for the following decade.

The Decadal Survey panel described the national strategy outlined in its report as having *"as its overarching objective a program of scientific discovery and development of applications that will enhance economic competitiveness, protect life and property, and assist in the stewardship of the planet for this and future generations."*

The Committee will hear testimony from three witnesses. Two of the witnesses were the co-chairs of the Decadal Survey, and they will discuss the findings and recommendations of their report. The third witness will discuss the application of remote sensing data to meet agricultural, resource management, and other needs.

Background

Although the development of decadal strategies for astronomy and astrophysics research has been the practice since the 1980s, the report examined at this hearing represents the first such decadal strategy to be developed for Earth science. The National Academies of Science and Engineering was asked to undertake the task by NASA's Office of Earth Science, NOAA's National Environmental Satellite Data and Information Service (NESDIS), and the U.S. Geological Survey (USGS) Geography Division. The study was overseen by an 18-member executive committee and carried out be seven thematically organized panels with a total of more than 80 members. The panels consisted of the following:

1. Earth Science Applications and Societal Needs
2. Land-use Change, Ecosystem Dynamics and Biodiversity
3. Weather (including space weather and chemical weather)
4. Climate Variability and Change
5. Water Resources and the Global Hydrologic Cycle
6. Human Health and Security
7. Solid-Earth Hazards, Resources and Dynamics

Major Findings and Recommendations of the Decadal Survey

Interim Report

The Decadal Survey panel issued an interim report in the spring of 2005, entitled *Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation.* In that report, the panel made the following observations:

"The current U.S. civilian Earth observing system centers on the environmental satellites operated by NOAA; the atmosphere-, biospheres-, ocean-, ice-, and land-observation satellites of NASA's Earth Observing System (EOS); and the Landsat satellites, which are operated by a cooperative arrangement involving NASA, NOAA, and the U.S. Geological Survey (USGS). Today, this system of environmental satellites is at risk of collapse. Although NOAA plans to modernize and refresh its weather satellites, NASA has no plan to replace its EOS platforms after their nominal six-year lifetimes end (beginning with the Terra satellite in 2005), and it has canceled, descoped, or delayed at least six planned missions, including the Landsat Data Continuity Mission.

"These decisions appear to be driven by a major shift in priorities at a time when NASA is moving to implement a new vision for space exploration. This change in priorities jeopardizes NASA's ability to fulfill its obligations in other important presidential initiatives, such as the Climate Change Research Initiative and the subsequent Climate Change Science Program. It also calls into question future U.S. leadership in the Global Earth Observing System of Systems, an international effort initiated by the current Administration. The Nation's ability to pursue a visionary space exploration agenda depends critically on its success in applying knowledge of the Earth to maintain economic growth and security at home.

"Moreover, a substantial reduction in Earth observation programs today will result in a loss of U.S. scientific and technical capacity, which will decrease the competitiveness of the United States internationally for years to come. U.S. leadership in science, technology development, and societal applications depends on sustaining competence across a broad range of disciplines that include the Earth sciences."

Final Report

In January 2007, the National Academies released the final report of the Decadal Survey panel. In the final report, the panel reiterated the concerns expressed in the Interim Report about the Nation's system of environmental satellites being *"at risk of collapse."* In that regard, the final report states: *"In the short period since the publication of the Interim Report, budgetary constraints and programmatic difficulties at NASA and NOAA have greatly exacerbated this concern. At a time of unprecedented need, the Nation's Earth observation satellite programs, once the envy of the world, are in disarray."*

The Decadal Survey panel made a series of recommendations in its report to address the perceived problems. The first was an overarching recommendation that:

- **The U.S. Government, working in concert with the private sector, academe, the public, and its international partners, should renew its investment in Earth observing systems and restore its leadership in Earth science and applications.**

Other major recommendations of the report are as follows:

- **NASA should ensure continuity of measurements of precipitation and land cover by:**
  - **Launching the Global Precipitation Measurement (GPM) mission in or before 2012**
  - **Securing a replacement to Landsat 7 data before 2012**

The Landsat program has operated for over 30 years. Landsat images are used by governments, the research community, and the private sector in a wide variety of applications including monitoring of crop productivity, documenting changes in land use, water management, monitoring and tracking "red" tides, monitoring changes in coastal wetlands, citing power and transportation routes, monitoring changes in glacial features, and many other applications. The current Landsat instrument is in need of replacement. It is currently producing degraded imagery and may not have many more years of functionality.

- **In addition to implementing the re-baselined National Polar-orbiting Operational Environmental Satellite System (NPOESS) and Geostationary Operational Environmental Satellite (GOES) program and completing research missions currently in development, NASA and NOAA should undertake a set of 17 recommended missions, comprised of small (<$300 million), medium ($300 million to $600 million), and large ($600 million to $900 million) cost missions, and phased appropriately over the**

next decade. Larger facility-class (>$1 billion) missions are not recommended. [See Attachment 1 for list of recommended missions.]

NOAA operates two satellite systems that collect data for weather forecasting. The polar satellites orbit the Earth and provide information for medium to long-range weather forecasts. The geostationary satellites gather data above a fixed position on the Earth's surface and provide information for short-range warnings and current weather conditions. Both of these systems are scheduled for replacement through the NPOESS and GOES–R programs, respectively.

Significant cost and schedule problems have arisen in the NPOESS program. A number of instruments that would have provided continuity of our current Earth and climate monitoring programs were planned to fly on the NPOESS satellites were eliminated from the program to reduce its cost and complexity.

The suite of 17 priority missions outlined by the NAS are intended to provide continuity of the Earth science and climate data sets as well as advance our understanding of the Earth system and climate.

- **U.S. civil space agencies should aggressively pursue technology development that supports the recommended missions; plan for transitions to continue demonstrably useful research observations on a sustained, or operational, basis; and foster innovative new space-based concepts.**

The above recommendation includes three main points: NASA, as the primary space research and development agency should increase funding allotted for the early design and testing phases of technology development that serves the research and operational missions recommended in this NAS report. The Panel believes that greater investments made early in the development of new instrumentation and spacecraft will result in more robust designs and prototypes which then move to development and deployment on a smoother, less risky path (and therefore with a more predictable budget).

The Panel also recommends that NASA develop a new Program to take on newer, more risky projects and demonstrate their feasibility and applicability to research and operational needs. The NAS recommends this program focus on low-cost missions ($100–200 million) and that it have a strong focus on technical innovation as well as education and training of future scientists and engineers working in the field of Earth and climate science.

Finally, the Panel recommended that NOAA allocate increased funding to support the transition of NASA-developed satellites and spacecraft that are identified as having operational utility to NOAA's missions.

The transition from research to operations continues to be a problem for NOAA because there are no funds specified for the transition activities that must occur to move research satellites and spacecraft to operational status. Consequently, procurement programs for operational systems now often carry these costs resulting in higher risks of cost overruns, schedule slips, and higher risk of breaks in operational data for weather forecasting.

- **The NASA Science Mission Directorate should develop a science strategy for obtaining long-term, continuous, stable observations of the Earth system that are distinct from observations to meet requirements by NOAA in support of numerical weather prediction.**
- **Earth system observations should be accompanied by a complementary system of observations of human activities and their effects on Earth, and socioeconomic factors should be considered in the planning and implementation of Earth observation missions and in developing the Earth Information System.**
- **NOAA, working with the Climate Change Science Program and the international Group on Earth Observations, should create a climate data and information system to meet the challenge of ensuring the production, distribution, and stewardship of high-accuracy climate records from NPOESS and other relevant observational platforms.**
- **As new Earth observation missions are developed, there must also be early attention to developing the requisite data processing and distribution system, and data archive. Distribution of data should be free or at low cost to users, and provided in an easily-accessible manner.**
- **NASA should increase support of its Research and Analysis (R&A) program to a level commensurate with its ongoing and planned missions.**

Data gathered by satellite-based instruments and spacecraft must be properly documented, analyzed and archived to be useful. Funding for these activities has traditionally lagged behind funding for the hardware and software needed to build, launch and operate satellite-based instruments and spacecraft. In addition to R&A cuts made as part of an overall budget-balancing exercise, cost-overruns experienced in the development and procurement of an observing system may lead to cuts in the funding allocated for analysis of the data generated by the observing system.

- **NASA, NOAA, and USGS should increase their support for Earth system modeling, including provision of high-performance computing facilities and support for scientists working in the areas of modeling and data assimilation.**
- **A formal interagency planning and review process should be put into place that focuses on effectively implementing the recommendations made in the present decadal survey report and sustaining and building the knowledge and information system for the next decade and beyond.**
- **NASA, NOAA, and USGS should pursue innovative approaches to educate and train scientists and users of Earth observations and applications. A particularly important role is to assist educators in inspiring and training students in the use of Earth observations and the information derived from them.**

Witnesses

Dr. Richard Anthes, President of the University Corporation for Atmospheric Research (UCAR):

Dr. Anthes served as Co-Chair of the Decadal Survey. He has conducted research directed at better understanding of tropical cyclones and mesoscale meteorology, as well as on techniques for doing atmospheric sounding. He chaired the 2003 National Academies Committee on NASA–NOAA Transition of Research to Operations. Dr. Anthes is a fellow of the American Meteorological Society and the American Geophysical Union.

Dr. Berrien Moore, Professor and Director of the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire:

Dr. Moore served as Co-Chair of the Decadal Survey. His research has focused on the carbon cycle, global biogeochemical cycles, and global change. Dr. Moore has served on a number of NASA advisory committees, and he chaired the Scientific Committee of the International Geosphere-Biosphere Programme (IGBP) from 1998–2002. He currently serves on the Science Advisory Board of NOAA and the Advisory Board of the National Center for Atmospheric Research (NCAR).

Dr. Anthes and Dr. Moore will discuss the criteria the Decadal Survey Committee used to determine the priorities recommended in the Report. They will also discuss the utility of the research and application activities to the Nation and the international community. Dr. Anthes and Dr. Moore will also provide an assessment of the President's FY 2008 budget request for NASA and NOAA as they relate to the recommendations included in the Decadal Survey Report.

Honorable James Geringer, Director of Policy at the Environmental Systems Research Institute in Wyoming and former Governor of Wyoming:

Former Wyoming Governor James Geringer has been active in the Alliance for Earth Observations and was the force behind the Western Governors Association's call for a National Integrated Drought Information System (NIDIS).

Governor Geringer will discuss the utility of data derived from the current Earth observing systems we have in place. He will discuss the applicability of remote sensing data to agriculture, natural resource management, municipal water supply management, and to tourism and recreation. The Governor will provide information regarding the accessibility of remote sensing data to different user communities and discuss the role of private sector companies that provide value-added products from remote sensing data. He will also provide a perspective on how widely remote sensing data are used by government and industry people working in agriculture and natural resource management.

ATTACHMENT 1

TABLE 2.1 Launch, orbit, and instrument specifications for the recommended NOAA missions. Missions are listed in order of ascending cost within each launch timeframe.

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 - 2013—Missions listed by cost				
CLARREO (NOAA portion)	Solar and Earth radiation characteristics for understanding climate forcing	LEO, SSO	Broadband radiometer	$65 M
GPSRO	High accuracy, all-weather temperature, water vapor, and electron density profiles for weather, climate and space weather	LEO	GPS receiver	$150 M
Timeframe 2013 – 2016				
XOVWM	Sea surface wind vectors for weather and ocean ecosystems	LEO, SSO	Backscatter radar	$350 M

TABLE 2.2 Launch, orbit, and instrument specifications for the recommended NASA missions. Missions are listed in order of ascending cost within each launch timeframe.

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 – 2013, Missions listed by cost				
CLARREO (NASA portion)	Solar radiation: spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer	$200 M
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	$300 M
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	$300 M
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	$700 M
Timeframe: 2013 – 2016, Missions listed by cost				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	$300 M
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser	$400 M
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar	$450 M
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers	$550 M
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	$800 M
Timeframe: 2016 -2020, Missions listed by cost				
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter	$300 M
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer	$450 M
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system	$450 M
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers	$500 M
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	$600 M
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar	$650 M

[a] Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational high accuracy SST measurement.

Chairman GORDON. It is 10 o'clock and time to get started, so good morning, everyone. I would like to welcome our witnesses to today's hearing. We look forward to hearing your views.

As you know, last week the Science and Technology Committee held the first hearing in Congress on the just-released report of the Intergovernmental Panel on Climate Change (IPCC). That hearing provided a useful glimpse into the current scientific understanding of climate change.

It is clear that the advances in our scientific understanding of climate change are critically dependent on the data collection and modeling enabled by our investments in Earth science research and applications at NOAA and NASA. In addition, those investments play a crucial role in improving the accuracy of our weather forecasts, monitoring land use, and managing our natural resources.

In short, this nation needs to continue to invest in robust systems of environmental satellites.

Two witnesses—or rather two years ago, one of today's witnesses, Dr. Berrien Moore, stated that the *Interim Report of the National Academies' Decadal Survey* had concluded that the Nation's system of environmental satellites was, and I quote, "at risk of collapse." That was a sobering assessment.

Now the Decadal Survey is finished, and we will be hearing their findings and recommendations today.

One of those findings is particularly troubling. And once again, I quote: *"In the short period since the publication of the Interim Report, budgetary constraints and programmatic difficulties at NASA have greatly exacerbated this concern. At a time of unprecedented need, the Nation's Earth observation satellite programs, once the envy of the world, are in disarray."*

I don't think the National Academies could be clearer than that in voicing its concern. So at today's hearing, I want to get answers to the following questions.

When the Decadal Survey panel says that the Nation's Earth observation satellite programs "are in disarray," what does that mean in specific terms?

What is the impact of that disarray, and why does it matter?

And, what needs to be done to fix this situation?

Of course, in these times of tight budgets, some will look at the Academies' recommendations and simply say, "We can't afford to do more than we are now." However, the simple fact of the matter is that our nation is getting ready to spend a lot of money to deal with climate change in the coming years, both public dollars and private dollars.

We will continue to need good data to make sure that those investments are wise ones and that we are getting the intended results. I am worried that we are going to be "flying blind" if we don't ensure that the Nation's environmental satellite system is up to the task of collecting critical climate science data, and the Decadal Survey is sounding the alarm that unless we take steps to reverse the current decline, we aren't going to have the satellite system we need in the coming decade.

And we have got a lot to discuss today, so I want to welcome our witnesses, and now, I want to recognize Ranking Member Hall for any opening remarks that he would like to make.

[The prepared statement of Chairman Gordon follows:]

PREPARED STATEMENT OF CHAIRMAN BART GORDON

Good morning.

I'd like to welcome our witnesses to today's hearing.

We look forward to hearing your views.

As you know, last week the Science and Technology Committee held the first hearing in Congress on the just-released report of the Intergovernmental Panel on Climate Change (IPCC).

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In addition, those investments play a crucial role in improving the accuracy of our weather forecasts, monitoring land use, and managing our natural resources.

In short, this nation needs to continue to invest in a robust system of environmental satellites.

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That was a sobering assessment.

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One of those findings is particularly troubling.

Namely: *"In the short period since the publication of the Interim Report, budgetary constraints and programmatic difficulties at NASA have greatly exacerbated this concern. At a time of unprecedented need, the Nation's Earth observation satellite programs, once the envy of the world, are in disarray."*

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- What is the impact of that disarray, and why does it matter?
- And, what needs to be done to fix the situation?

Of course, in these times of tight budgets, some will look at the Academies recommendations and simply say *"we can't afford to do more than we are now."*

However, the simple fact of the matter is that the Nation is getting ready to spend a lot of money to deal with climate change in the coming years.

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I'm worried that we are going to be "flying blind" if we don't ensure that the Nation's environmental satellite system is up to the task of collecting critical climate science data. . .and the Decadal Survey is sounding the alarm that unless we take steps to reverse the current decline, we aren't going to have the satellite system we will need in the coming decade.

Well, we have a lot to discuss today.

I again want to welcome our witnesses, and I now want to recognize Ranking Member Hall for any opening remarks he would care to make.

Mr. HALL. Mr. Chairman, I want to thank you for calling today's hearing to examine the recently released *Decadal Survey on Earth Sciences,* produced by the National Academies. This report, which provides strategic advice to the government on the scope and goals of future Earth-observing missions, especially those flown by NASA and NOAA, will need great help to guide the federal investment decisions now and in the years ahead of us.

I want to begin by thanking Dr. Anthes and Dr. Moore and all your colleagues that served with you on the National Academies committee. Drafting the first ever of such a report could not have been easy, but I am certain that the community is stronger, and I thank you for it, and perhaps more cohesive as a result. And I hope you will tell your friends and colleagues that we are grateful for their very hard work.

Governor Geringer, thank you for taking time from your very busy schedule today to describe how remote sensing data and products are used by industry and government. I want to add, parenthetically, that in my State of Texas and for many residents in the western states, monitoring and measuring drought conditions is rapidly gaining importance.

During the last Congress, I was able to work with my friends here in the House to draft and pass a bill establishing the National Integrated Drought Information System, and I am glad that the President agreed to sign it into law. But having said that, to many in this room, weather forecasting products are about all we understand. Governor—we look forward to your testimony, and those of you who ran your governments about the numerous other applications of remote sensing information.

Beyond articulating the science questions and missions, the Survey challenges the government to reassess the amount of funding dedicated to Earth science. It urges government to increase investment in NASA's Earth sciences program by $500 million a year, about a 33 percent increase over current levels.

This presents the Administration and Congress with a tremendous challenge. It is no mystery to everyone in this room that NASA is struggling to afford its current slate of programs, from human space flight to aeronautics, astrophysics, planetary sciences, and redirecting funding from any of these activities is not an option. We need all of them. Either NASA maintains the status quo with, perhaps, marginal adjustments in content to its Earth sciences program or its top-line funding should be increased. And I strongly prefer the latter. I think that is what we have to do. We have to increase these fundings.

The report also recommends new missions for NOAA that would total $565 million over the next 10 years. I hope the witnesses will help us understand what weather forecasting improvements these missions would provide and why the Decadal Survey recommends them.

In closing, Mr. Chairman, I do want to be clear. I support the Decadal Survey and its recommendations. It lays out a course of research that should be followed. It raises questions that are of immediate importance to our way of living, and, if truly implemented, it will provide planning tools that will help future generations monitor and mitigate the effect of changes to Earth's weather system. Unfortunately, in the current budget climate, I fear we cannot fully implement the recommendations. And in that vein, I intend to ask hard questions today about which of the recommendations and missions are most important.

I look forward to hearing from our witnesses and yield back the balance of my time.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Mr. Chairman, thank you for calling today's hearing to examine the recently released *Decadal Survey on Earth Sciences* produced by the National Academies. This report, which provides strategic advice to the government on the scope and goals of future Earth observing missions, especially those flown by NASA and NOAA, will be help guide federal investment decisions now and in the years to come.

I want to begin by thanking Dr. Anthes and Dr. Moore, and all your colleagues that served with you on the National Academies committee. Drafting the first-ever such report could not have been easy, but I am certain the community is stronger, and perhaps more cohesive as a result, and I hope you'll tell your friends and colleagues that we are grateful for their hard work.

Governor Geringer, thank you for taking time from your busy schedule to be with us today to describe how remote sensing data and products are used by industry and government. I want to add, parenthetically, that in my State of Texas, and for many residents in the western states, monitoring and measuring drought conditions is rapidly gaining importance. During the last Congress I was able to work with my friends here in the House to draft and pass a bill establishing the National Integrated Drought Information System, and I'm glad the President agreed to sign it into law.

But having said that, to many in this room, weather forecasting products are about all we understand. Governor, we look forward to your testimony about the numerous other applications of remote sensing information.

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I look forward to hearing from our witnesses and yield back the balance of my time.

Chairman GORDON. Thank you, Mr. Hall.

I ask unanimous consent that all additional opening statements be submitted by the Committee Members to be included in the record. Without Mr. Sensenbrenner's objection, so ordered.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good Morning. Thank you Mr. Chairman for calling this hearing to examine the findings and recommendations of the National Academies report *"Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond,"* also known as the Decadal Survey.

Today's report represents the first decadal strategy developed for Earth Science. The Survey Panel has made a series of recommendations to address the perceived problems regarding our nation's system of environmental satellites. I am aware that budgetary constraints and programmatic difficulties at the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) have contributed to the degradation of our Earth observation programs, specifically the NOAA satellites for data collection and forecasting.

I recognize that our nation's ability to pursue a visionary space exploration agenda depends on its success in applying greater knowledge of the Earth and I look forward to hearing the panel's recommendations. Further, I am interested in hearing the witnesses' thoughts on how the U.S. Government should proceed with funding for Earth Science and Climate Science Research for the upcoming fiscal year and beyond.

I look forward to the testimony of today's witnesses.

[The prepared statement of Mr. Mitchell follows:]

PREPARED STATEMENT OF REPRESENTATIVE HARRY E. MITCHELL

Thank you, Mr. Chairman.

Last week, we heard from some of the world's top scientists about the growing threat of global warming who reported to this committee some of the important findings of the International Panel on Climate Change.

I think many of us were concerned about what they had to say, and troubled by the scientific data that demonstrates the threat of global warming and climate change isn't simply a threat—it's happening all across the world.

I got a sense from my colleagues at that hearing that many in this Congress on both sides of the aisle believe that the United States has an important and unique role to play in solving the climate crisis.

The United States is a world leader in scientific discovery and innovation, and I think that most of the American people would agree that we should use our unique spirit and ingenuity for good.

We have especially succeeded when it comes to space exploration. We put a man on the Moon, have discovered so much about our galaxy, and the universe. We have worked with the international community to build a space station.

Yet not all of the important things we have discovered are about space. We have also learned about ourselves, and the planet Earth.

NASA and NOAA satellites have been instrumental in monitoring so many things about the Earth. Everything from temperatures and wind patterns to changes in land, ocean tides, and glacial features—and so much more.

The Earth observation systems we use are critical to enhancing our understanding of the planet, and critical to understanding how global warming is affecting all of us.

The Decadal Survey report that these observation systems are at "the risk of collapse" and are in "disarray" is unacceptable. The report makes clear that the state of these systems is because of "major shift in priorities" by the Administration. If that's the case, it's time for new priorities.

I'm encouraged by the recommendations of the Decadal Survey panel that we should invest in the technology that will grow our ability to make further scientific discoveries, and I look forward to hearing their testimony today.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

It takes a tenacious group of people to scrutinize our Earth observational challenges and to make recommendations on what we might do to ensure we are able to improve our forecasting and observational capabilities. I am pleased the members of the Decadal Survey committee were up to the task. The findings of the report are a wake-up call and will help scientists and policy-makers consider future missions flown by NASA and NOAA in addition to understanding the consequences of gaps in our observational capabilities.

I am especially concerned about the future capabilities of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and am glad that the Decadal Survey Committee has not endorsed many of the proposed cost-cutting measures to limit the escalating costs of the program. I realize NPOESS has been plagued by cost-overruns, but I believe we have to carefully weigh the long-term impact of removing NPOESS sensors on our global environmental monitoring capabilities. NPOESS oversight will continue by this committee and we welcome your survey's wisdom in determining the most strategic future for the program.

Finally, coherent integration is imperative in successful observation, and I look forward to learning more about how we can ensure that the consumers of Earth observation information can use this data. I thank our witnesses for being here today and look forward to their testimony.

[The prepared statement of Mr. Neugebauer follows:]

PREPARED STATEMENT OF REPRESENTATIVE RANDY NEUGEBAUER

Mr. Chairman:

Thank you for holding this hearing. I welcome the opportunity to take part in this important discussion and look forward to hearing from our distinguished panelists.

As we discovered from the hearing last week, climate change is an extremely important issue, yet controversial at the same time. While most of us agree that global warming is occurring, there are disputes regarding the cause and degree of this change. Part of this disagreement stems from the evolving nature of science.

Science is a process of constant re-evaluation of old hypotheses and theories, collection of new data, and continuous development of new models and approaches to critical questions. In order to properly understand climate change, it is critical that we have access to accurate data and technology. Therefore, I look forward to hearing the expert testimonies and recommendations of the panelists regarding the satellite technology we need to continue to gather accurate Earth, atmospheric, and climate data.

For many years the U.S. has led the world when it comes to space exploration and scientific development. I look forward to working with my colleagues in this regard to ensure that the U.S. will continue to be a global leader of research, technology, and innovation.

We in Congress, and in this committee especially, are called upon to make scientific and environmental policy that will affect our economy; our security; and our general welfare; and not just for us, but for future generations of Americans, as well.

Thank you.

Chairman GORDON. We are fortunate to have three distinguished witnesses at today's hearing. I will now yield to Representative Udall to introduce the first witness.

Mr. UDALL. Thank you, Mr. Chairman. Good morning.

It is my privilege to introduce Dr. Richard Anthes today. He is the President of the University Corporation for Atmospheric Research, otherwise known as UCAR, a non-profit consortium of 70 member universities that award Ph.D.s in atmospheric and related sciences. He is the co-chair of the National Research Council's Earth Science Decadal Survey. Dr. Anthes is a highly-regarded atmospheric scientist, author, educator, and administrator who has contributed considerable research to the field. He has published over 100 peer-reviewed articles and books and participated on or chaired over 400—excuse me, 40 different U.S./national committees. Dr. Anthes is currently President of the American Meteorological Society. His many research contributions involve particularly the areas of tropical cyclones and mezoscale meteorology, including the development of the first successful three-dimensional model of the tropical cyclone, which evolved into one of the world's most widely used mezoscale models, the Penn State NCAR Mezoscale Model, which is now in its fifth generation.

Welcome, Dr. Anthes.

Dr. ANTHES. Thank you very much, Congressman Udall. I don't think I have ever been introduced by a Congressman before, and that saves me 30 seconds of my five minutes.

I would like to start out with——

Chairman GORDON. If you don't mind, sir, let us go ahead, and we will recognize the other witnesses——

Dr. ANTHES. Oh, okay.

Chairman GORDON.—and then we will begin with you. But you are correct, you were well introduced there.

Our second witness is Dr. Berrien Moore, who is the other co-chair of the National Academies' Decadal Survey. Dr. Moore is a Professor and Director of the Institute for the Studies of Earth, Oceans, and Space at the University of New Hampshire. Welcome.

Our third witness is former Wyoming Governor, Dr. Jim—I mean, rather Jim Geringer. Governor Geringer has been very active in the Alliance for Earth Observations, and he was the force behind the Western Governors Association call for a National Integrated Drought Information System.

I want to welcome each of you and look forward to your testimony.

You will each be given five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing. With my friend, Mr. Rohrabacher's indulgence, I will say that we will try to be liberal with your five minutes, because this is very important, and we want to hear from you.

When all three of you have completed your testimony, we will begin with questions. Each Member will have five minutes to question the panel.

Doctor, we will begin with you.

STATEMENT OF DR. RICHARD A. ANTHES, PRESIDENT, UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH (UCAR); CO-CHAIR, COMMITTEE ON EARTH SCIENCE AND APPLICATIONS FROM SPACE, NATIONAL RESEARCH COUNCIL, THE NATIONAL ACADEMIES

Dr. ANTHES. Okay. Thank you very much.

Mr. Chairman, Ranking Minority Member, and Members of the Committee, thanks for inviting us here to testify here today.

I would like—this is one of my favorite rooms in the whole world, because of that—the statement, "Where there is no vision, the people perish," from Proverbs 29:18. I think that is what we need to keep our eye on, not the individual observations, not the individual dollars, but we really do need a vision for Earth science and applications from space. And I just love that saying. It is a perfect lead in.

Our vision from our Decadal Survey is carried over, actually, from the Interim Report. And I want to read it to you. I think it is very important. I believe in it deeply. "Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability."

So this is the dual message, the dual vision of our report, that understanding the Earth is one of the most exciting intellectual challenges we can think of. And it is also critically important for applications of immediate and long-term benefit to humanity.

As detailed in our report and further emphasized by the latest issue of the IPCC, which came out a couple weeks ago, our society is faced with a number of profound scientific and societal challenges, including climate change and all of the aspects of the climate change that is occurring at an unprecedented rate. And yet, at a time when the need has never been greater, we are faced with an Earth observation program that will dramatically diminish in capability over the next five to ten years.

As you mentioned already, our Interim Report said that the system of U.S. environmental satellites was at risk of collapse. This judgment was based on the observed precipitous decline in funding and the consequent cancellation, descoping, and delay of a number of critical missions and instruments.

Otherwise, let me interject here and deviate from my prepared talk a little bit.

This is not primarily about money and decreasing budgets. It is primarily about doing the job that needs to be done for society, and the modest investments that are required will repay themselves many times over. So please focus on the benefits to society, the intellectual challenges, and what we are proposing as a balanced system rather than the declining budgets.

So I have been asked, you know, what will we lose if we don't do what the Decadal Survey mentions. And I think my colleague, Dr. Moore, will give you some examples, but let me just give you some examples that are not really in the Survey.

Weather forecasts and warnings may start becoming less accurate. We have seen a tremendous run-up of increased accuracy in weather forecasting and warnings over the last 30 years, primarily because of Earth observations from space. The Hurricane Katrina forecast was incredibly accurate, saving, perhaps, 100,000 lives, one of the few bright spots in that whole tragic episode. But we are actually in danger, if the observations continue to decrease, of losing that improving weather forecasts and warning capabilities. Very serious.

The Earth is warming because of a small imbalance in radiation between the sun and the Earth, a very small difference between two very large terms. What is coming in from the sun, a huge number and what is going back out to space. We need to measure that small imbalance very accurately. We need to measure what is coming in from the sun and what is going out from the Earth so that we know whether the Earth is going to warm up faster, whether it is going to slow down in its warming up, and finally, when we reach a new equilibrium and there is no more change. Climate models have improved steadily over the past years, but they are far from perfect. They don't do very well on regional scales, which is what we are really interested in. Is the dryness in the west going to continue? Are hurricanes going to become more frequent or more intense? Those kinds of things. So we need the observations to improve the climate models. We could never rely on models without observations.

Sea levels are rising, and the ice around the Earth is melting. But how fast? Is this going to accelerate—these things going to accelerate or decelerate, slow down? We have got to measure sea level and the ice around the Earth, especially in Greenland.

As I mentioned, there is controversy about whether the frequency and intensity of tropical storms or hurricanes is going to increase or decrease. We simply don't know. And without observations, we won't be able to resolve that critical issue.

And finally, Earth science is built fundamentally on observations, not theory and not models. And it will—it is impossible for me to sit here and predict what discoveries won't be made in the next 20 years if we don't have observation. I can't do that, but I can surely say that if the present trend of decreasing observations continues, we will—the rate of scientific progress will be greatly slowed.

So the plan we recommend calls for undertaking 17 new NASA and NOAA missions from the period 2008 to 2020 as well as restoring some of the capabilities lost on NPOESS and GOESS.

Our recommendations for NASA can be implemented in a cost-effective manner. I think my colleague, Dr. Moore, will talk about this. We are merely—to do the required program, and again, the required program is what is important, not the money, we need to simply restore the NASA Earth sciences budget to what it was five years ago.

Finally, implementing these missions will not only greatly reduce the risks to the people of our country in the world of natural hazards of all kinds, it will support more efficient management of natural resources, including water, energy, fisheries, ecosystems that support the economy and our lives and—so that the cost of this program is repaid many times over.

Thank you very much for the opportunity to appear before you today, and I look forward to any questions that you might have.

Thank you.

[The prepared statement of Dr. Anthes follows:]

PREPARED STATEMENT OF RICHARD A. ANTHES

Mr. Chairman, Ranking Minority Member, and Members of the Committee: thank you for inviting me here to testify today. My name is Richard Anthes, and I am the President of the University Corporation for Atmospheric Research, a consortium of 70 research universities that manages the National Center for Atmospheric Research, on behalf of the National Science Foundation, and additional scientific education, training and support programs. I am also the current President of the American Meteorological Society. I appear today in my capacity as Co-Chair of the National Research Council (NRC)'s Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future.

The National Research Council is the unit of the National Academies that is responsible for organizing independent advisory studies for the Federal Government on science and technology. In response to requests from NASA, NOAA, and the USGS, the NRC has recently completed a "decadal survey" of Earth science and applications from space. ("Decadal surveys" are the 10-year prioritized roadmaps that the NRC has done for 40 years for the astronomers; this is the first time it is being done for Earth science and applications from space.) Among the key tasks in the charge to the decadal survey committee were to:

- Develop a consensus of the top-level scientific questions that should provide the focus for Earth and environmental observations in the period 2005–2020; and
- Develop a prioritized list of recommended space programs, missions, and supporting activities to address these questions.

The NRC survey committee has prepared an extensive report in response to this charge, which I am pleased to be able to summarize here today. Over 100 leaders in the Earth science community participated on the survey steering committee or its seven study panels. It is noteworthy that this was the first Earth science decadal survey, and the committee and panel members did an excellent job in fulfilling the charge and establishing a consensus—a task many previously considered impossible. A copy of the full report has also been provided for your use.

The committee's vision is encapsulated in the following declaration, first stated in the committee's interim report, published in 2005:

> "Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability."

As detailed in the committee's final report, and as we were profoundly reminded by the latest report from the International Panel on Climate Change (IPCC), the world faces significant and profound environmental challenges: shortages of clean and accessible freshwater, degradation of terrestrial and aquatic ecosystems, increases in soil erosion, changes in the chemistry of the atmosphere, declines in fisheries, and above all the rapid pace of substantial changes in climate. These changes are not isolated; they interact with each other and with natural variability in complex ways that cascade through the environment across local, regional, and global scales. Addressing these societal challenges requires that we confront key scientific questions related to ice sheets and sea level change, large-scale and persistent shifts in precipitation and water availability, transcontinental air pollution, shifts in ecosystem structure and function in response to climate change, impacts of climate change on human health, and occurrence of extreme events, such as hurricanes, floods and droughts, heat waves, earthquakes, and volcanic eruptions.

Yet at a time when the need has never been greater, we are faced with an Earth observation program that will dramatically diminish in capability over the next 5–10 years.

Last April, my co-chair, Dr. Berrien Moore, came before Congress to testify in response to release of the committee's 2005 interim report. His testimony highlighted the key roles played by NASA and NOAA over the past 30 years in advancing our understanding of the Earth system and in providing a variety of societal benefits through their international leadership in Earth observing systems from space. He noted that while NOAA had plans to modernize and refresh its weather satellites, NASA had no plans to replace its Earth Observing System platforms after their nominal six year lifetimes end. He also noted that NASA had canceled, scaled back, or delayed at least six planned missions, including a Landsat continuity mission. This led to the main finding in the interim report, which stated "this system of environmental satellites is at risk of collapse."

Since the publication of the interim report, the Hydros and Deep Space Climate Observatory missions were canceled; the flagship Global Precipitation Mission was delayed for another two and a half years; significant cuts were made to NASA's Research and Analysis program: the NPOESS Preparatory Project mission was delayed for a year and a half; a key atmospheric profiling sensor planned for the next generation of NOAA geostationary satellites was canceled; and the NPOESS program breached the Nunn-McCurdy budget cap. As you have all heard, the certified NPOESS program delays the first launch by three years, eliminates two of the planned six spacecraft, and de-manifests or de-scopes a number of instruments, with particular consequences for measurement of the forcing and feedbacks that need to be measured to understand the magnitude, pace, and consequences of global and regional climate change. It is against this backdrop that I discuss the present report.

As you will see in the report, between 2006 and the end of the decade, the number of operating missions will decrease dramatically and the number of operating sensors and instruments on NASA spacecraft, most of which are well past their nominal lifetimes, will decrease by some 35 percent, with a 50 percent reduction by 2015 (see Figure 1 below). Substantial loss of capability is likely over the next several years due to a combination of decreased budgets and aging satellites already well past their design lifetimes. **This will result in an overall degradation of the system of Earth observing satellites, with the following potential consequences:**

- After decades of steady improvement, weather forecasts, including those of severe weather such as hurricanes, may start becoming less accurate, putting more people at risk and diminishing the proven economic value of accurate forecasts.
- The ozone hole in the stratosphere has apparently reached its maximum intensity. Models predict it will start to slowly recover. Without observations we may not be able to verify its recovery or explain why it is occurring.
- Earth is warming because of a small imbalance between incoming solar radiation and outgoing radiation from Earth. Measuring this small imbalance is critical to determining how fast Earth is warming and when the warming will stop. Without the measurements we are recommending will not be able to quantify how this net energy imbalance is changing.
- Climate models have improved steadily over the years, but are far from perfect. We need observations of the Earth system, the atmosphere, oceans, land and ice to verify and improve the climate models. These models have real impact on the U.S. economy, in predicting El Niño and other seasonal fluctuations in climate, which are used in energy, water and agriculture management.

- Sea level is rising and ice around the world is melting, yet there is uncertainty in how fast these are occurring and whether or not they are accelerating or decelerating. Without the observations we are recommending, we will be unable to know for sure how these rates are changing and what the implications will be for coastal communities.
- There is controversy about whether the frequency and intensity of hurricanes are increasing as the climate warms; observations of the atmosphere and oceans are required to resolve this important issue.
- The risk of missing early detection of earthquakes, tsunamis, and volcanic eruptions will increase.
- Air quality forecasts, which require the global perspectives of satellites to identify pollution transport across borders, will become less accurate, with negative implications for both human health and urban pollution management efforts.
- Earth science is based fundamentally on observations. While it is impossible to predict what scientific advances will not occur without the observations, or what surprises (like the ozone hole) we will miss, we can be sure the rate of scientific progress will be greatly slowed without a robust set of Earth observations.

In its report, the committee sets forth a series of near-term and longer-term recommendations in order to address these troubling trends. It is important to note that this report does not "shoot for the Moon," and indeed the committee exercised considerable constraint in its recommendations, which were carefully considered within the context of challenging budget situations. Yet, while societal applications have grown ever-more dependent upon our Earth observing fleet, the NASA Earth science budget has declined some 30 percent in constant-year dollars since 2000 (see Figure 2 below). This disparity between growing societal needs and diminished resources must be corrected. This leads to the report's overarching recommendation:

> *"The U.S. Government, working in concert with the private sector, academe, the public, and its international partners, should renew its investment in Earth observing systems and restore its leadership in Earth science and applications."*

The report outlines near-term actions meant to stem the tide of capability deterioration and continue critical data records, as well as forward-looking recommendations to establish a balanced Earth observation program designed to directly address the most urgent societal challenges facing our nation and the world (see Figure 3 below for an example of how nine of our recommended missions support in a synergistic way one of the societal benefit areas—extreme event warnings). It is important to recognize that these two sets of recommendations are not an "either/or" set of priorities. *Both* near-term actions *and* longer-term commitments are required to stem the tide of capability deterioration, continue critical climate data records, and establish a balanced Earth observation program designed to directly address the most urgent societal challenges facing our nation and the world. It is important to "right the ship" for Earth science, and we simply *cannot* let the current challenges we face with NPOESS and other troubled programs stop progress on all other fronts. Implementation of the "stop-gap" recommendations concerning NPOESS, NPP, and GOES–R are important—and the recommendations for establishing a healthy program going forward are equally as important. Satisfying near-term recommendations without placing due emphasis on the forward-looking program is to ignore the largest fraction of work that has gone into this report. Moreover, such a strategy would result in a further loss of U.S. scientific and technical capacity, which could decrease the competitiveness of the United States internationally for years to come.

Key elements of the recommended program include:

1. Restoration of certain measurement capabilities to the NPP, NPOESS, and GOES–R spacecraft in order to ensure continuity of critical data sets.
2. Completion of the existing planned program that was used as a baseline assumption for this survey. This includes (but is not limited to) launch of GPM in or before 2012, securing a replacement to Landsat 7 data before 2012.
3. A prioritized set of 17 missions to be carried out by NOAA and NASA over the next decade (see Tables 1 and 2 below). This set of missions provides a sound foundation for Earth science and its associated societal benefits well beyond 2020. The committee believes strongly that these missions form a minimal, yet robust, observational component of an Earth information system that is capable of addressing a broad range of societal needs.

4. A technology development program at NASA with funding comparable to and in addition to its basic technology program to make sure the necessary technologies are ready when needed to support mission starts over the coming decade.
5. A new "Venture" class of low-cost research and application missions that can establish entirely new research avenues or demonstrate key application-oriented measurements, helping with the development of innovative ideas and technologies. Priority would be given to cost-effective, innovative missions rather than ones with excessive scientific and technological requirements.
6. A robust NASA Research and Analysis program, which is necessary to maximize scientific return on NASA investments in Earth science. Because the R&A programs are carried out largely through the Nation's research universities, such programs are also of great importance in supporting and training next generation Earth science researchers.
7. Sub-orbital and land-based measurements and socio-demographic studies in order to supplement and complement satellite data.
8. A comprehensive information system to meet the challenge of production, distribution, and stewardship of observational data and climate records. To ensure the recommended observations will benefit society, the mission program must be accompanied by efforts to translate raw observational data into useful information through modeling, data assimilation, and research and analysis.

Further, the committee is particularly concerned with the lack of clear agency responsibility for sustained research programs and the transitioning of proof-of-concept measurements into sustained measurement systems. To address societal and research needs, both the quality and the continuity of the measurement record must be assured through the transition of short-term, exploratory capabilities, into sustained observing systems. The elimination of the requirements for climate research-related measurements on NPOESS is only the most recent example of the Nation's failure to sustain critical measurements. Therefore, our committee recommends that the Office of Science and Technology Policy, in collaboration with the relevant agencies, and in consultation with the scientific community, should develop and implement a plan for achieving and sustaining global Earth observations. This plan should recognize the complexity of differing agency roles, responsibilities, and capabilities as well as the lessons from implementation of the Landsat, EOS, and NPOESS programs.

Mr. Chairman, the observing system we envision will help establish a firm and sustainable foundation for Earth science and associated societal benefits through the year 2020 and beyond. It can be achieved through effective management of technology advances and international partnerships, and broad use of satellite science data by the research and decision-making communities. Our report recommends a path forward that restores U.S. leadership in Earth science and applications and averts the potential collapse of the system of environmental satellites. As documented in our report, this can be accomplished in a fiscally responsible manner, and I urge the committee to see that it is accomplished.

Thank you for the opportunity to appear before you today. I am prepared to answer any questions that you may have.

Supporting Tables and Graphics

Supporting Tables and Graphics

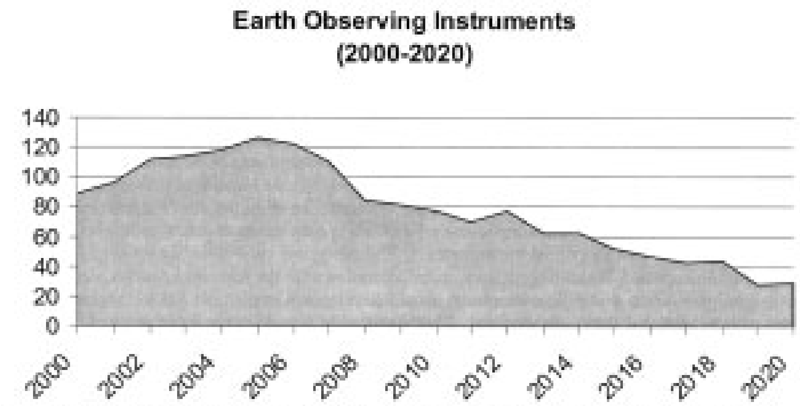

Figure 1. Number of current and planned U.S. space-based Earth Observations instruments, not counting the recommended missions in the Committee's report. For the period from 2007 to 2010, missions were generally assumed to operate for four years past their nominal lifetimes. SOURCE: Information from NASA and NOAA websites for mission durations.

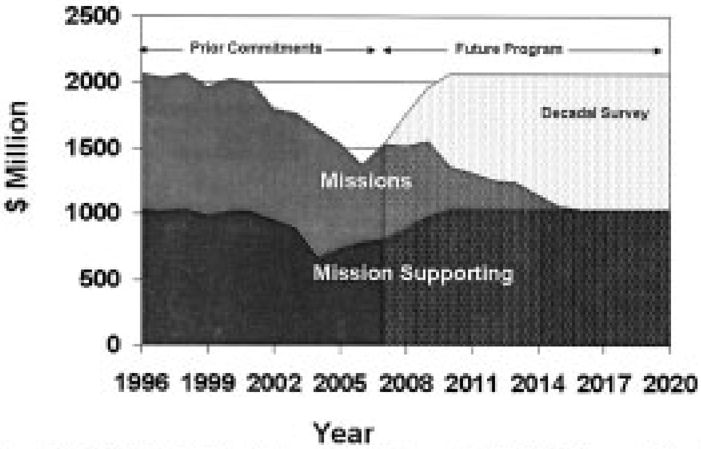

Figure 2. NASA budget for Earth Sciences adjusted to constant FY 2006 dollars and adjusted for the effects of full-cost accounting.

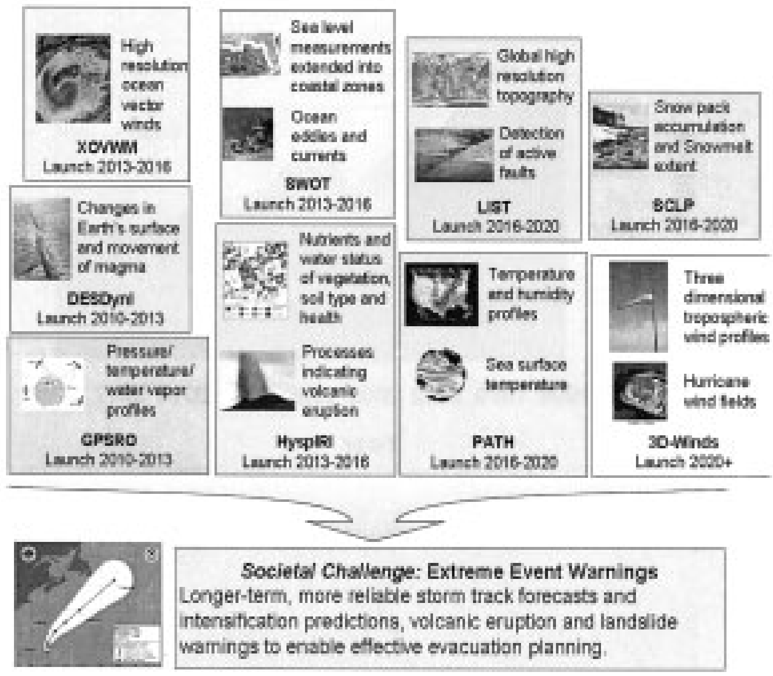

Figure 3. Illustration showing how recommended missions work together to address societal challenges. Numerous additional examples are available in Chapter 2 of the final report.

TABLE 1. Launch, orbit, and instrument specifications for the recommended NOAA missions. Shade colors denote mission cost categories as estimated by the NRC committee. Green and blue shadings represent medium ($300 million to $600 million) and small (<$300 million) missions, respectively. Detailed descriptions of the missions are given in Part II of the final report, and Part III provides the foundation for selection.

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 - 2013—Missions listed by cost				
CLARREO (Instrument Re-flight Components)	Solar and Earth radiation characteristics for understanding climate forcing	LEO, SSO	Broadband radiometers	$65 M
GPSRO	High accuracy, all-weather temperature, water vapor, and electron density profiles for weather, climate and space weather	LEO	GPS receiver	$150 M
Timeframe 2013 – 2016				
XOVWM	Sea surface wind vectors for weather and ocean ecosystems	LEO, SSO	Backscatter radar	$350 M

TABLE 2. Launch, orbit, and instrument specifications for the recommended NASA missions. Shade colors denote mission cost categories as estimated by the NRC ESAS committee. Pink, green, and blue shadings represent large ($600 million to $900), medium ($300 million to $600 million), and small (<$300 million) missions, respectively. Missions are listed in order of ascending cost within each launch timeframe. Detailed descriptions of the missions are given in Part II of the final report, and Part III provides the foundation for selection.

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 – 2013, Missions listed by cost				
CLARREO (NASA portion)	Solar and Earth radiation, spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer	$200 M
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	$300 M
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	$300 M
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	$700 M
Timeframe: 2013 – 2016, Missions listed by cost				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	$300 M
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser	$400 M
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar	$450 M
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers	$550 M
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	$800 M

Timeframe: 2016 -2020, Missions listed by cost				
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter	$300 M
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer	$450 M
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system	$450 M
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers	$500 M
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	$600 M
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar	$650 M

[a] Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational high accuracy SST measurement.

BIOGRAPHY FOR RICHARD A. ANTHES

Since 1988 Dr. Richard Anthes has been President of the University Corporation for Atmospheric Research (UCAR). He is a highly regarded atmospheric scientist, author, educator and administrator who has contributed considerable research to the field. UCAR is a non-profit consortium of 70 member universities that award Ph.D.s in atmospheric and related sciences. UCAR manages the National Center for Atmospheric Research, in addition to collaborating with many international meteorological institutions.

Dr. Anthes has published over 100 peer-reviewed articles and books and participated on or chaired over 40 different U.S. national committees. His many research contributions in the areas of tropical cyclones and mesoscale meteorology include the development of the first successful three-dimensional model of the tropical cyclone which evolved into one of the world's most widely used mesoscale models, the Penn State-NCAR mesoscale model, now in its fifth generation (MM5). In recent years he became interested in the radio occultation technique for sounding Earth's atmosphere and was a key player in the highly successful proof-of-concept GPS/MET experiment. This grew into an internationally sponsored project called COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate) which recently launched a globe-spanning constellation of six satellites, expected to improve weather forecasts, monitor climate change, and enhance space weather research.

Dr. Anthes has also received numerous awards for his sustained contributions to the atmospheric sciences. In October 2003 he was awarded the Friendship Award by the Chinese government, the most prestigious award given to foreigners, for his contributions over the years to atmospheric science and weather forecasting in China. He is Co-Chair of the National Research Council's Committee on Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. Dr. Anthes is currently President of the American Meteorological Society.

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9 February 2007

The Honorable Bart Gordon
Chairman
Committee on Science and Technology
U.S. House of Representatives
Suite 2320 Rayburn House Office Building
Washington, DC 20515-6301

Dear Chairman Gordon:

Thank you for your invitation to provide testimony on the February 13th hearing entitled, "*National Imperatives for Earth and Climate Science Research and Applications Investments over the Next Decade*". I will be happy to do so.

In accordance with the rules of your committee governing testimony, I would like to inform you of the federal funding I received in FY 2006 on behalf of the University Corporation for Atmospheric Research (UCAR). Please note that I am listed as the Principal Investigator (PI) on UCAR's National Science Foundation (NSF) Cooperative Agreement, which encompasses many awards from NSF, our principal funding agency, to UCAR. The total amount of the cooperative agreement from NSF for 2006 was $122,967,831.

Please contact me if you would like more information on my funding sources.

Sincerely,

Richard A. Anthes
President

Chairman GORDON. Thank you. Right on time.
Dr. Moore.

STATEMENT OF DR. BERRIEN MOORE III, UNIVERSITY DISTINGUISHED PROFESSOR, DIRECTOR, INSTITUTE FOR THE STUDY OF EARTH, OCEANS, AND SPACE, UNIVERSITY OF NEW HAMPSHIRE; CO-CHAIR, COMMITTEE ON EARTH SCIENCE AND APPLICATIONS FROM SPACE, NATIONAL RESEARCH COUNCIL, THE NATIONAL ACADEMIES

Dr. MOORE. Mr. Chairman, Mr. Chairman, Ranking Minority Member, and Members of the Committee, thank you inviting—for inviting me to testify today.

I would like to repeat what my colleague, Rick Anthes, said. At a time when the need has never been greater, we are faced with an Earth observation program that will dramatically diminish in capability over the next five to ten years.

Now we can ask, "Why did this occur?" Simply stated, the NASA Earth science budget declined, in real terms, by a third from the year 2000 to now. And as you well know, technical and managerial difficulties in the NPOESS program offset the budget increases for NOAA's planned satellites over the same period. And regardless of where or whether blame is placed, we are still in the same situation. That is where we are.

The Survey set forth a strategy for a strong, balanced national program in Earth science to reverse this trend. It recommends, as Rick said, that the Nation commit to leadership in Earth's observations in part through implementing a series of 17 missions carefully chosen to augment and replace our aging satellite fleet. The set of recommended 15 new missions to NASA may seem large numerically, but we believe that through focusing on smaller missions and avoiding large, multi-instrumented platforms, a robust strategy for the future of Earth science can be achieved with reasonable investments. As Rick Anthes just said, the program could be restored if we could just simply get back to the year 2000 levels.

I would like to call attention to what happened. It is in my written testimony. To show this 33 percent decline in real terms from 2000 to the present.

What about the future?

Is the President's fiscal year 2008 budget adequately preparing us for the future?

In short, no.

The President's budget provides only a brief respite to a dramatically diminished observational system. The respite, lasting until 2010, does allow us to move forward with plans to measure global rainfall, the Global Precipitation Mission, and general land cover characteristics to the Landsat, but by 2012, the budget will leave NASA's Earth science with nearly 50 percent less buying power in comparison to the year 2000 and unable to pursue the critical topics just described by my colleague. The fall by 2012 will put us at a 20-year low in real terms for Earth science.

NOAA's budget also appears to be inadequate to solve the cost of growth within the NPOESS and GOES–R programs and to mitigate some of the NPOESS losses by reinstating the solar and Earth radiation measurements, which, as Rick just said, are central to the climate system. Reinstating the high-resolution measurements of the atmospheric ozone profiles, a key measurement to allow to understand the post-CFC era, and realizing an operational active radar-based measurement of sea surface winds.

Can anything be done now about the Committee's recommendations for the next decade?

Definitely, yes.

For instance, the Survey presented a set of guidelines for managing the implementation of the new missions that included early investments in technologies. This is an opportunity for the new decade, starting now. NASA should consider investing $10 million per year per mission across the first half of the 15 missions. That takes an investment of $70 million. With that investment, we could actually begin to implement the Decadal Survey right now.

It would also send a message that we are proceeding to develop the needed and recommended Earth observing program. These investments would avoid technological surprises that have plagued other programs. And I think that, in itself, is a reason to go forward with that kind of technology-based building.

Now how can we justify increasing resources in this time of particularly difficult budget issues, as Congressman Hall noted?

I believe it is because of the benefits: more reliable forecasts of infectious diseases; the identification of active faults and the monitoring of crustal movements to improve building code designs in earthquake-prone regions; better weather forecasts, particularly for severe storms; climate predictions based on better understanding of carbon sources and sinks, ocean temperature, ice sheet volume changes, and, as we have noted, the inputs from the sun and the thermal response of the Earth; enhanced precipitation and drought forecasts to improve water quality management and water resource management; and improved land-use agriculture to ocean productivity forecasts for better planning harvest cycles; and finally, more reliable air quality forecasts to enable effective urban pollution management and to protect the elderly and other populations at risk.

Thank you very much, and I will be happy to answer any further questions.

[The prepared statement of Dr. Moore follows:]

PREPARED STATEMENT OF BERRIEN MOORE III

Mr. Chairman, Ranking Minority Member, and Members of the Committee: thank you for inviting me here to testify today. My name is Berrien Moore, and I am a Professor of systems research at the University of New Hampshire and Director of the Institute for the Study of Earth, Oceans, and Space. I appear today, like Dr. Anthes, in my capacity as Co-Chair of the National Research Council (NRC)'s Committee on Earth Science and Applications from Space.

As you know, the NRC is the unit of the National Academies that is responsible for organizing independent advisory studies for the Federal Government on science and technology. The NRC has been conducting decadal strategy surveys in astronomy for four decades, but this is the first decadal survey in Earth science and applications from space.

On March 2, 2006, I testified before this committee at a hearing entitled, *NASA's Science Mission Directorate: Impacts of the Fiscal Year 2007 Budget Proposal.* At that hearing, I showed the table below, which is taken from the 2005 Interim Report of our study. This table shows the effects of the FY '06 budget.[1] I then discussed my concerns about the proposed cuts in the FY '07 budget, especially the continuing reductions in funding for Research and Analysis, which I believed was having a very negative effect on a program already pared to the bone.

Canceled, Descoped, or Delayed Earth Observation Missions
(from the April 2005 Pre-Publication of the Interim Report of the Decadal Survey on Earth Science and Applications from Space)

Mission	Measurement	Societal Benefit	Status
Global Precipitation Measurement (GPM)	Precipitation	Reduced vulnerability to floods and droughts; improved capability to manage water resources in arid regions; improved forecasts of hurricanes	Delayed
Atmospheric Soundings from Geostationary Orbit (GIFTS—Geostationary Imaging Fourier Transform Spectrometer)	Temperature and water vapor	Protection of life and property through improved weather forecasts and severe storm warnings	Canceled
Ocean Vector Winds (active scatterometer follow-on to QuikSCAT)	Wind speed and direction near the ocean surface	Improved severe weather warnings to ships at sea; improved crop planning and yields through better predictions of El Niño	Canceled
Landsat Data Continuity—bridge mission (to fill gap between Landsat-7 and NPOESS)	Land cover	Monitoring of deforestation; identification of mineral resources; tracking of the conversion of agricultural land to other uses	Canceled
Glory	Optical properties of aerosols; solar irradiance	Improved scientific understanding of factors that force climate change	Canceled
Wide Swath Ocean Altimeter (on the Ocean Surface Topography Mission, OSTM)	Sea level in two dimensions	Monitoring of coastal currents, eddies, and tides, all of which affect fisheries, navigation, and ocean climate	Instrument canceled—descope of an enhanced OSTM

Since my appearance, there have been further cancellations and delays of NASA missions and dramatic and deleterious changes in plans for the next generation of NOAA meteorological satellites, especially regarding their capability to support the needs for prediction, assessment, and mitigation of the effects of climate change.

With this as background, I will now turn to the questions posed to me in advance of this hearing.

1. How did the Decadal Survey committee determine the priorities that it recommended the Nation pursue in Earth and climate science research and applications?

As noted in testimony of my co-chair, Dr. Richard Anthes, the Decadal Survey's vision, which was first expressed in the committee's 2005 Interim Report,[2] is for a program of Earth science research and applications in support of society. The present report reaffirms this vision, the fulfillment of which requires a national commitment to a program of Earth observations from space in which practical benefits to humankind play an equal role with the quest to acquire new knowledge about the Earth.

The Interim Report described how satellite observations have been critical to scientific efforts to understand the Earth as a system of connected components, including the land, oceans, atmosphere, biosphere, and solid-Earth. It also gave examples of how these observations have served the Nation, helping to save lives and protect property, strengthening national security, and contributing to the growth of our

[1] Note that the Glory mission was subsequently restored. The latest plan for LDCM is to implement the mission as a free-flyer.

[2] National Research Council, *Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation,* The National Academies Press, Washington, D.C., 2005.

economy[3] through provision of timely environmental information. However, the Interim Report also identified a substantial risk to the continued availability of these observations, warning that the Nation's system of environmental satellites was "at risk of collapse." As noted above, in the short period since the publication of the Interim Report, budgetary constraints and programmatic difficulties at NASA and NOAA have greatly exacerbated this concern. At a time of unprecedented need, the Nation's Earth observation satellite programs, once the envy of the world, are in disarray.

The decadal survey was led by an Executive Committee that drew on the work of seven thematically-organized study panels:[4]

1. Earth science applications and societal needs.
2. Land-use change, ecosystem dynamics, and biodiversity.
3. Weather (including space weather[5] and chemical weather[6]).
4. Climate variability and change.
5. Water resources and the global hydrologic cycle.
6. Human health and security.
7. Solid-Earth hazards, resources, and dynamics.

As described in Chapter 2 of our final report, each of the panels used a common template in establishing priority lists of proposed missions (see Table 1 below). The potential to deliver tangible benefits to society was an overriding consideration for panel deliberations.

Because execution of even a small portion of the missions on the panels' short lists was not considered affordable, panels worked with each other and with members of the Executive Committee to pare the number of missions; they also developed synergistic mission "rollups" that would maximize science and application returns across the panels while keeping within a more affordable budget. Frequently, the recommended missions represented a compromise in an instrument or spacecraft characteristic (including orbit) between what two or more panels would have recommended individually without a budget constraint.

All the recommendations offered by the panels would merit support—indeed, the panels' short lists of recommendations were distilled from the over 100 responses that we received in response to a request for mission concepts, as well as other submissions—but the Executive Committee took as its charge the provision of a strategy for a strong, balanced national program in Earth science for the next decade that could be carried out with what are thought to be realistic resources. Difficult choices were inevitable, but the recommendations presented in this report reflect the committee's best judgment, informed by the work of the panels and discussions with the scientific community, about which programs are most important for developing and sustaining the Earth science enterprise.

The recommended NASA program can be accomplished by restoring the Earth science budget in real terms to the levels of the late 1990s.

[3] It has been estimated that one third of the $10 trillion U.S. economy is weather-sensitive or environment-sensitive (NRC, *Satellite Observations of the Earth's Environment: Accelerating the Transition of Research to Operations,* The National Academies Press, Washington, D.C., 2003).

[4] The Panel Chairs were members of the Executive committee.

[5] The term *space weather* refers to conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and that can affect human life and health.

[6] There is no single definition of *chemical weather,* but the term refers to the state of the atmosphere as described by its chemical composition, particularly important variable trace constituents such as ozone, oxides of nitrogen, and carbon monoxide. Chemical weather has a direct impact in a number of areas of interest for this study, especially air quality and human health.

TABLE 1. The eight prioritization criteria used by the panels to create relative rankings of missions. Note that these are guidelines; they are not in priority order, and they may not reflect all of the criteria considered by the panels.

1. Contribution to the most important scientific questions facing Earth sciences today (scientific merit, discovery, exploration)
2. Contribution to applications and policy making (societal benefits)
3. Contribution to long-term observational record of the Earth
4. Ability to complement other observational systems, including national and international plans
5. Affordability (cost considerations, either total costs for mission or costs per year)
6. Degree of readiness (technical, resources, people)
7. Risk mitigation and strategic redundancy (backup of other critical systems)
8. Significant contribution to more than one thematic application or scientific discipline

2. What are the practical benefits of the research and applications activities that your Decadal Survey recommended?

Our report presents a vision for the Earth science program; an analysis of the existing Earth observing system and recommendations to help restore its capabilities; an assessment of and recommendations for new observations and missions needed for the next decade; an examination of and recommendations concerning effective application of those observations; and an analysis of how best to sustain that observation and applications system. *A critical element of the study's vision is its emphasis on the need to place the benefits to society that can be provided by an effective Earth observation system on a par with scientific advancement.*

The integrated suite of space missions and supporting and complementary activities that are described in our report will support the development of numerous applications of high importance to society. Expected benefits of the fully-implemented program include:

- **Human Health**
  More reliable forecasts of infectious and vector-borne disease outbreaks for disease control and response.
- **Earthquake Early Warning**
  Identification of active faults and prediction of the likelihood of earthquakes to enable effective investment in structural improvements, inform land-use decisions, and provide early warning of impending earthquakes.
- **Weather Prediction**
  Longer-term, more reliable weather forecasts.
- **Sea Level Rise**
  Climate predictions based on better understanding of ocean temperature and ice sheet volume changes and feedback to enable effective coastal community planning.
- **Climate Prediction**
  Robust estimates of primary climate forcings for improved climate forecasts, including local predictions of the effects of climate change; determination in time and space of sources and sinks of carbon dioxide.
- **Freshwater Availability**
  More accurate and longer-term precipitation and drought forecasts to improve water resource management.
- **Ecosystem Services**
  More reliable land-use, agricultural, and ocean productivity forecasts to improve planting and harvesting schedules and fisheries management.
- **Air Quality**
  More reliable air quality forecasts to enable effective urban pollution management.
- **Extreme Storm Warnings**

Longer-term, more reliable storm track forecasts and intensification predictions to enable effective evacuation planning.

3. How consistent is the President's FY 2008 budget request for NASA and NOAA with the recommendations of the Decadal Survey Committee?

It is important to note we were, of course, not privy to the details of the President's fiscal year 2008 budget, which was developed prior to the release of our final report. The NRC report is a forward-looking document and therefore focuses primarily on the new missions; whereas, the Interim Report dealt with the difficulties and challenges of the Earth observing programs at NASA and NOAA, as they existed in early 2005.

Let me address first the President's FY '08 budget request for NASA Earth science. It is a mixture of some good news and bad news. The primary good news is the small bottom line increases for 2008 and 2009. These increases address the needs of currently planned missions already in development, the completion of which is consistent with the decadal survey's baseline set of assumptions.

Unfortunately, the out-year budgets reveal fundamental flaws in the budget and NASA's Earth science plans—the budgets are totally inadequate to accomplish the decadal survey's recommendations.

In 2010, the Earth science budget begins to decline again and reaches a 20-year low, in real terms, in 2012. This decline reflects that the 2008 budget contains no provision for new missions, nor does it allow us to address the significant challenges facing our planet. The 2008 budget also ignores our repeatedly stated concern about declines in the Research and Analysis portion of the Earth science budget. The Interim Report raised this concern about the FY 2006 budget and the importance of a robust Research and Analysis program is reaffirmed in the final report, but regrettably, the FY 08 budget for R&A is 13 percent below the FY '06 budget in real terms. These disturbing broad trends are captured in Figure 1.

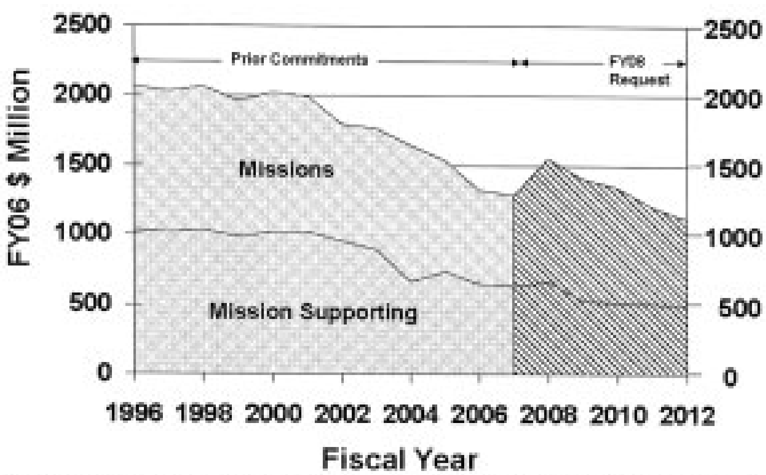


Figure 1: The NASA Earth Science Budget in constant FY06 dollars (normalized for full-cost accounting across entire timescale; assumes 3%/year inflation from 2006 to 2012). Mission supporting activities include Earth Science Research, Applied Sciences, Education and Outreach, and Earth Science Technology.

Before turning to NOAA, I want to emphasize that the problems in the out-years appear to be due entirely to the lack of adequate resources. In fact, at a NASA town-hall meeting that followed the release of our report on January 15, 2007 at the 2007 annual meeting of the American Meteorological Society, the head of NASA's Earth Science program stated that the recommendations in our report provided the road-map for the Earth Science program we *should* have.

The NOAA NESDIS budget picture is also a mixture of some good and bad news. In this case, the budget takes a small downturn in FY08, followed by significant growth in FY09–FY10, before turning down again in FY11 (Figure 2). It remains to be seen whether this ~$200 M/year growth in FY09 and FY10 can enable restoration of some of the lost capabilities to NPOESS and GOES–R. There appears to be no budgetary wedge for new starts. Finally, for a variety of reasons, the NOAA NESDIS budget is far from transparent, especially in the out-years, and the level of detail that is readily available makes it difficult to respond adequately to Committee's question.

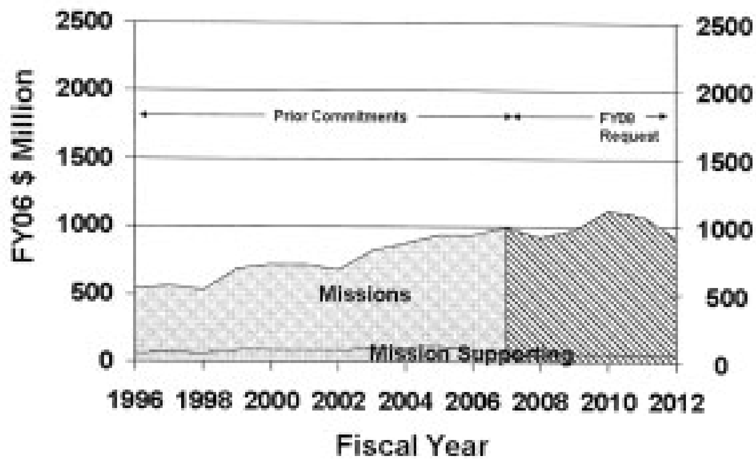


Figure 2: The NOAA NESDIS Budget in constant 2006 dollars (assumes 3 percent/year inflation from 2006-2012). Mission supporting activities include NOAA's Data Centers and Information Services, Data System Enhancements, Data Exploitation, and Information Services, and Facilities and Critical Infrastructure Improvements.

4. What will be the impact if present trends in Earth and climate science research and applications investments continue?

As detailed in our report and as summarized by my co-chair, between 2006 and the end of the decade, the number of operating U.S. missions will decrease dramatically and the number of operating sensors and instruments on NASA spacecraft, most of which are well past their nominal lifetimes, may decrease by some 35 percent. If present trends continue, reductions of some 50 percent reduction are possible by 2015.

Were this to pass, we would have chosen, in effect, to partially blind ourselves at a time of increasing need to monitor, predict, and develop responses to numerous global environmental challenges. Vital climate records, such as the measurement of solar irradiance and the Earth's response, will be placed in jeopardy or lost. Measurements of aerosols, ozone profiles, sea surface height, sources and sinks of important greenhouse gases, patterns of air and coastal pollution, and even winds in the atmosphere are among the numerous critical measurements that are at risk or simply will not occur if we follow the path of the President 2008 budget and the proposed out-year run out.

Taking this path, we will also forgo the economic benefits that would have come, for example, from better management of energy and water, and improved weather predictions.[7] Again, as my co-chair notes in his comments and testimony, without

[7] In a typical hurricane season, NOAA's forecasts, warnings, and the associated emergency responses result in a $3 billion savings. Two-thirds of this savings, $2 billion, is attributed to the reduction in hurricane-related deaths, and one-third of this savings, $1 billion, is attributed to a reduction in property-related damage because of preparedness actions. Advances in satellite information, data assimilation techniques, and more powerful computers to run more sophisticated numerical models, have lead to more accurate weather forecasts and warnings. Today,

action on the report's recommendations, a decades-long improvements in the skill in which we make weather forecasts will stall, or even reverse; this may be accompanied by diminished capacity to forecast severe weather events and manage disaster response and relief efforts. The Nation's capabilities to forecast space weather will also be at risk, with impacts on commercial aviation and space technology.[8]

The world is facing significant environmental challenges: shortages of clean and accessible freshwater, degradation of terrestrial and aquatic ecosystems, increases in soil erosion, changes in the chemistry of the atmosphere, declines in fisheries, and the likelihood of significant changes in climate. These changes are occurring over and above the stresses imposed by the natural variability of a dynamic planet, as well as the effects of past and existing patterns of conflict, poverty, disease, and malnutrition. Further, these changes interact with each other and with natural variability in complex ways that cascade through the environment across local, regional, and global scales. In summary, absent a reversal of the present trends for Earth observation capabilities, we see the following:

- **Weather forecasts:** After decades of steady improvement, weather forecasts, including those of severe weather such as hurricanes, may become less accurate, putting more people at risk and diminishing the proven economic value of accurate forecasts.
- **Earthquakes, tsunamis, landslides, and volcanic eruptions:** We risk missing early detection of these and other hazards. We also lose our ability to assess damage and mitigate the loss of further human life once they have occurred. Satellite monitoring of volcanic plumes, for example, has a very real impact on air traffic control.
- **Water resources:** We lose many of the needed observations to monitor the health of our water storage reservoirs, and predict droughts with sufficient time to mitigate their impact.
- **Oceans:** Sea level is rising and ice around the world is melting, yet there is uncertainty in how fast these are occurring and whether or not they are accelerating or decelerating. We will become less able address these issues, and assess their implications for our coastal communities.
- **Climate:** We are losing critical observations of the Earth system, the atmosphere, oceans, land, and ice needed to verify and improve the climate models. These models will be increasingly important to the U.S. economy because they best capture the likely patterns of future climate change and variability.
- **Ecosystems:** We lose the ability to assess the health of our forests, wetlands, coastal regions, fisheries, and farmlands and to determine the impact and effectiveness of regulations designed to protect our food supply.
- **Health:** Land-use, land cover, oceans, weather, climate, and atmospheric information observations, now used by public health officials to determine the effects of infectious diseases, skin cancers, chronic and acute illnesses resulting from contamination of air, food, and water are all at risk. As an example, air quality forecasts, which use the global perspective of satellites to identify pollution transport across borders, will become less accurate, with negative implications for both human health and urban pollution management efforts.

I would like to thank the Committee for inviting me to testify, and I would be delighted to answer any further questions.

Chairman GORDON. Governor.

NOAA's five-day hurricane forecasts, which utilize satellite data, are as accurate as its three-day forecasts were 10 years ago. The additional advanced notice has a significant positive effect on many sectors of our economy. See statement and references therein of Edward Morris, Director, Office of Space Commercialization, NOAA, Hearing on Space and U.S. National Power, Committee on Armed Services Subcommittee on Strategic Forces, U.S. House of Representatives, June 21, 2006. Available at: *http://www.legislative.noaa.gov/Testimony/morris062106.pdf*

[8] Ibid.

STATEMENT OF HONORABLE JAMES GERINGER, DIRECTOR OF POLICY AND PUBLIC SECTOR STRATEGY, ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE (ESRI)

Mr. GERINGER. Thank you, Mr. Chairman, Members of the Committee, Ranking Member Hall. I appreciate the opportunity to be with you today.

I am Jim Geringer. As you have introduced me, I am with the Environmental Systems Research Institute, a leader in geospatial information systems. I served as Governor of Wyoming. I also represent the Alliance for Earth Observations, which is a group of people who are interested in an observation system of a totally integrated type that includes academia, non-profits, non-governmental, as well as industrial members.

My past includes time as an ag-producer, a farmer. I have used Earth observation information for several years and also worked on the unmanned space program, launching, among other things, a Global Positioning Satellite system that we knew as NABSTAR, at the time.

I deeply appreciate what Dr. Moore and Dr. Anthes have put together through their committee. I serve on the Mapping Science Committee also under the National Research Council. I am not associated with their activity, but I very well understand the quality and breadth of reports that just—don't just happen. It takes a lot of effort.

My role here, I believe, is to speak from the practical point of view, those who have to do something with the information. For all of the college degrees that there might be, the Bachelors, the Masters, and the Ph.D.s, I think mine is more relevant as the BT, the "been there" degree.

As a former governor and ag-producer, my staff used to say, "It doesn't take a rocket scientist to be governor, but it helps."

One example I would give is what Congressman Hall already brought up, the National Integrated Drought Information System. My part of the Rocky Mountain west is still suffering from a significant drought. I know that we would certainly like to balance out what New York is getting right now.

Drought can last long and extend across larger areas than hurricanes, tornadoes, floods, earthquakes, and it causes hundreds of millions of dollars in losses, and it certainly dashes our hopes and dreams. And when the 19 western governors got together and said, "We would like to support the use of satellite and other observation information to lessen droughts' impact on our region," we requested the NIDIS system, as it is called, because rather than spending billions of dollars, federal dollars, in particular, on drought assistance after the fact, we would rather spend more on avoidance before the fact.

The strongest case for NIDIS and then extending on through the broader Earth observation activities is to enable risk management by individuals to make better judgment and policy decisions by business, by government, and shifting from our practice of reaction and restitution to one of prediction and mitigation.

The Decadal Survey goes far beyond just climate change. It highlights many other Earth science areas of practical benefit. Looking at what is happening with increased populations located in high-risk zones, such as earthquake faults or near sea coasts, the shortage of clean and accessible freshwater, the shortage of water, as a commodity, will be the dominate issue from here forward, human health and security, degradation of both terrestrial and aquatic ecosystems, soil erosion, invasive species, and certainly our opportunity to do disaster—better disaster management. So all of those are even beyond the climate change issues that have already been raised.

There is also a concern that I would bring to you that the lack of access to and the relevance of remotely-sensed data frustrates a lot of users. We need to devote more time asking the users what they need and help them find it. Many times it is available. They just don't know it is there. We need a streamlined process for accessing remotely-sensed data by the public, policy-makers, educational communities, as well as industry.

In terms of three broad areas of recommendation I would bring to you, based on the Decadal Survey. Number one, enable the best possible personal and policy decisions, the best information for all kinds of people, providing our citizens with information, technology, and tools to monitor and respond in their own way to our changing world, protecting their lives, livelihood, and property. Number two, provide an Integrated Earth Observation System, otherwise known as IEOS, to assure U.S. competitiveness. Our American competitiveness is slipping without the projects and the missions described by the two co-chairmen here. And number three, designate clear leadership responsibilities to resolve the issues and attain the goals identified in the Decadal study.

Our United States private sector capabilities lead all other nations today. With activities such as GoogleEarth, Microsoft, Yahoo, and our own product at ESRI, providing online mapping sites using remotely-sensed imagery that the public now takes for granted. Other private sector companies, such as GeoEye and DigitalGlobe, well known in Colorado, provide high-resolution imagery for tourism, real estate, insurance companies to use. It has enabled corrections to legal descriptions, settled land ownership disputes, Light Detection and Ranging, or LiDAR, sensors are used to map terrain and to define flood plain mapping and allow state and local governments to aid in their own development decisions.

There are so many sources that are brought to bear in addition to satellite imagery to mitigate and respond to catastrophic events.

And I was also asked to specifically address how Earth observations are used in the agricultural sector. But first, let me address how they are not.

Current Earth observations are highly fragmented, with different systems that were set at different times by different organizations and by different Congresses for different reasons, and few, if any, of them are cross-correlated, especially within the federal space. NOAA has their weather observations. The FAA has surface observations. The USGS has stream gauging, and the Department of Agriculture, through the NRCS, employs snow pack telemetry. We do not have a coherent, integrated system to deliver each of the products so that we can tell their relationships and their interrelationships.

Satellite remote sensing, indeed, though, is broadly used in sustainable agriculture: forestry; responsible natural resource stewardship both in the public and the private domain; monitoring foreign and domestic yearly yields on harvests of food and fiber to predict where the balances and the imbalances might occur; measuring soil erosion from wind and water; evaluating the impact of climate change; detecting the presence of invasive species, plants, animals, insects, and diseases that affect a wide range of agriculture; detecting and measuring contamination of soil, water, and air resources; looking at landscape health; measuring resources involved with the development of biofuels, and certainly with the shift from food production to biofuels being able to monitor that.

So remotely-sensed observations support the entire agriculture value stream from monitoring and detecting change, identifying solutions, taking action, and then finding out, in return, what the result of those actions were.

There are many uses of agriculture in—such as hyperspectral imagery by individual farmers and ranchers all the way up to what you are doing on this committee, Mr. Chairman and Members of the Committee. Whatever the user is, they want objective, timely, and accurate information. And timeliness is, by far, the most important, because the value of information is the highest when uncertainty is the highest, and it is certainly—uncertainty is certainly common in agriculture.

One of the statements in the report says that satellites—and I quote, “Satellite observations have spatial and temporal resolution limitations and hence, alone, do not provide a picture of Earth’s system that is sufficient for understanding all of the key physical, chemical, and biological processes.” What we need is a system of space, ground, airborne, and ocean-based sensors, both public and private, that can gather complementary information and can be integrated with a minimum of duplication. In addition, we need a national network of web-based information integration of how our collective efforts, and I had proposed in the appendix attached to my written remarks how we could integrate that through a geospatial-enabled information system.

So to sum up, we can build on the Decadal Study results by ensuring that the United States has long-term Earth-observation capability and that it is maintained, certainly whatever we heard this morning is we are not even maintaining; addressing the void in leadership and how the vision can pull it all together; addressing a single point of contact or program office within the Office of Science and Technology Policy; improving our research to operations efforts across all agencies; establishing a common, integrated information infrastructure readily available through web portals to the public and policy-makers alike; implement the U.S. Integrated Earth Observation System, IEOS, which is part of the Global Earth Observation System of Systems, or GEOSS; and then begin a dialogue with the private sector, industry, academia, and non-governmental organizations to assure that all observation assets respond to the needs of all of our various sectors, as well as to consider new technology solutions. A high-level commission that includes the private sector, non-governmental, and governmental representatives, particularly state and local, could further examine and develop an integrated plan for Earth observations.

Mr. Chairman, thank you.

[The prepared statement of Mr. Geringer follows:]

PREPARED STATEMENT OF JAMES GERINGER

Chairman Gordon, Ranking Member Hall, Members of the Committee, special guests, ladies and gentlemen. I am Jim Geringer, currently Director of Policy and Public Sector Strategy for Environmental Systems Research Institute (ESRI), the industry leader for geospatial information systems. I served as Governor of Wyoming from 1995 to 2003. I am also a representative of the Alliance for Earth Observations, a nonprofit initiative to unite the private sector in the mission to promote the understanding and use of Earth observations for societal and economic benefit. My past includes time spent as an agricultural producer and user of Earth observation information and several years with the unmanned space program configuring remote sensing satellites. I will relate some of my perspective from each of these roles.

We each benefit from Earth science, remote sensing and location-based information every day. Through TV, newspapers, PDAs and online information, we check the weather, the latest headlines and map out where to meet someone for dinner. On a broader scale, we can track indicators of change across our planet. The National Oceanic and Atmospheric Administration (NOAA) reported that last year was the warmest on record for the United States. My part of the Rocky Mountain West continues to suffer extreme drought. Last week's report from the Intergovernmental Panel on Climate Change (IPCC) confirms what we already knew anecdotally—that human activity is adversely affecting our climate.

Today's discussion centers on Earth science and applications from space and the requisite analytical tools that are necessary to make use of the data. As a former governor, agricultural producer and now involved with geospatial technology, I support the programs dealing with Earth science, applications, and observational technologies for public use, business decisions, and everyday personal choices.

I thank Drs. Berrien Moore and Rick Anthes for their leadership as Co-Chairs of the National Research Council (NRC) study, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond,* which is the focus of this hearing. I congratulate them and the other members of the Committee for an exceptional report. I serve on a related committee under the NRC, the Mapping Science Committee, so I know that the quality and breadth of reports such as this don't just happen; they require a very dedicated and concerted effort.

Response to the Report

Quoting from the report, "the United States' extraordinary foundation of global observations is at great risk. Between 2006 and the end of the decade, the number of operating missions will decrease dramatically and the number of operating sensors and instruments on NASA spacecraft, most of which are well past their lifetimes, will decrease by 50 percent." A fifty percent reduction in today's space-based information systems is in sharp contrast to ever increasing demand.

Quoting further, the Committee was "challenged by the rapidly changing budgetary environment of NASA and NOAA environmental-satellite programs. By definition, decadal surveys are forward-looking documents that build on a stable foundation of existing and approved programs. In the present survey, the foundation eroded rapidly over the course of the study." It is difficult maintain your vision from a crumbling vantage point.

I offer three recommendations to the Committee for your consideration and deliberation:

- Enable the best possible **personal and policy decisions** by providing our citizens with information, technology and tools to monitor and respond to our changing world, thereby protecting lives and property;
- Provide an integrated Earth observation system to assure U.S. **competitiveness;**
- Designate clear **leadership** responsibilities to resolve the issues and attain the goals identified in the Decadal Study.

Enable the Best Decisions

The American people need and deserve the most comprehensive and timely information possible about our world. The value of objective, timely, and accurate information has never been higher. We all would like to have predictable certainty and security, in our lives. The value of information is high when uncertainty is high. Today nearly every issue we face has increasing uncertainty which drives the necessity for better information. We devote funding and resources to modern medicine to keep our bodies healthy using the best information; likewise, we should have quality information about our nation's food supply, water supply, energy, climate change and national security or face more and more uncertainty. In today's world of RSS feeds, 24-hour news channels and e-mails that propagate rumor far faster than truth, information that is dangerously incomplete is being used to influence decision-makers. Today's media and Internet capabilities can and should provide more and better information. Remote sensing with the right analytical technology can provide an objective and accurate assessment of the situation before decisions are made with information that has not yet been validated.

We should develop a culture among agencies and levels of government to share data, applications and predictions, then serve the results to the public so that we individually and collectively are more self-reliant, less vulnerable and can assure long-term sustainability for our world.

A policy-maker in Washington, a water resource manager in the West, a farmer in Indiana each must have good information upon which to base decisions. We must have access to the most accurate and comprehensive science information to develop a policy of sustainability for ourselves and for future generations.

Earth Observations Are Vital to American Competitiveness

Integrated Earth observation capabilities are vital to American competitiveness. The Decadal Survey helps us realize that the U.S. Earth observation capability is not keeping up with expectations and our competitiveness is at risk. We must have the global information infrastructure that is critical to our interconnected society. Comprehensive science information ensures that decisions will be made based on evidence rather than anecdotes. Long-term, sustained data is needed to identify trends. Without U.S. long-term climate data, the IPCC assessment would not have been possible.

Small satellites such as the Disaster Monitoring Constellation (DMC) from the United Kingdom, Algeria, China, Nigeria and Turkey, provide information for disaster prediction and mitigation. But one of the most effective applications has been the monitoring of opium production in Afghanistan. A constellation of low-cost satellites showed that the area under opium cultivation grew to a record 165,000 hectares in 2006 compared to 104,000 hectares in 2005. The U.S. is not alone in innovative approaches.

On June 21, 2004, the Western Governors unanimously adopted a report entitled, *Creating a Drought Early Warning System for the 21st Century: The National Integrated Drought Information System.* I encourage the Members to download a copy from *http://www.westgov.org/wga/publicat/nidis.pdf.* I was pleased to provide testimony on their behalf before the Senate Committee on Commerce, Science & Transportation, Subcommittee on Disaster Prevention & Prediction last April that helped with the passage of H.R. 5136 authorizing NIDIS. Last week the President proposed $4.4 million in the FY 2008 budget to fund it.

The strongest case for NIDIS is to enable risk management by individuals, businesses and governments, dramatically shifting from our practice of reaction and response to one of prediction and mitigation. Our competitive capability will increase with better risk management. We cannot do this without accurate and regular satellite observations. With better sensors, data, applications, tools and ever-improving technology we should reward risk management over resignation to the elements.

Of all the commodities sought in our marketplaces today, none will affect our competitiveness in the future more than water. Not oil or gold or pork bellies, but water. Our municipalities must have timely information that enables water policies that minimize or eliminate water shortages, farmers to plant alternative crops, ranchers to locate alternatives for grazing, river barges to anticipate low flows in navigable waterways, and health agencies to control disease.

Space sensors and satellite observations improve our understanding and response to climate change to sustain international competitiveness. In today's global economy, innovation is the key to competitiveness. The United States must stay at the forefront of Earth observation and geospatial technologies to better forecast and mitigate the impact of climate change, natural disasters and not only lead the competition but leave a more sustainable world for our children. The motivations and aspirations of the next-generation workforce are being shaped today. We should be setting a long-range vision in place to encourage today's youth to pursue science, math, technology and engineering professions to assure future innovation and competitiveness.

Our commitment today to technology and greater knowledge of the Earth would allow us to better protect life and property and create unprecedented opportunities to promote economic vitality. The right instruments and information systems enable our ability to make forecasts that help anticipate outbreaks of infectious disease, ensure adequate water availability and quality, or increase agricultural productivity.

The recommendations by the NRC report would enable a global view of issues and activities. But a global view alone is not sufficient to make policy or decisions. We need researchers, geospatial modeling and analysis that integrate pertinent sources of data. We should promote the use of established standards and protocols to assimilate data from multiple sensors and sources—including commercial providers, State and local governments, academia and international partners—and provide the data through user-friendly web portals.

The U.S. private sector capabilities lead other nations. Google, Microsoft, Yahoo and MapQuest provide online mapping sites with remotely sensed imagery that we take for granted. In the private sector, companies such as GeoEye and DigitalGlobe provide high-resolution satellite imagery. Tourism, real estate and insurance companies routinely use remote sensing information available online. High-resolution imagery has enabled corrections to legal descriptions and settled ownership disputes of land parcels. Light Detection and Ranging, or LiDAR sensors are used extensively to map terrain and elevation allowing state and local governments to aid in planning and development decisions.

Dr. Glenn Hill of Texas Tech University used 3–D imaging to catalog and preserve the archaeological heritage in Mesa Verde National Park. If space-based technology were developed to produce images of the quality created by Hill's team, high-definition 3–D images of entire national parks would enhance our ability to manage our national parks. These and many other examples point out how public expectations continue to increase for good science and timely assessment.

I affirm the comment in the NRC report that "Satellite observations have spatial and temporal resolution limitations and hence do not alone provide a picture of the Earth system that is sufficient for understanding all of the key physical, chemical, and biological processes." We need a system of space, ground, airborne and ocean-based sensors, both public and private, that can gather complementary information and can be integrated with a minimum of duplication. In addition we need a national network information integration that can be provided by collective efforts such as a Geographic Information System for the Nation described in the paper attached to my written testimony as Appendix A.

Clear Leadership is Essential

Clear leadership is essential to resolve the issues and attain the goals identified in the Decadal Study. The report before you calls for increased funding to improve our current national Earth monitoring capability. Yes, funding is important but the essential missing element is leadership. Scientific assessment, increased budgets, improved technical capabilities, and coordinated public-private engagement must be accompanied by designated, consolidated leadership. Critical elements including satellite and aircraft sensors, in situ instruments such as stream gauges, and geospatial information systems, have been fragmented among our federal agencies, always a secondary mission, never the priority responsibility.

Earth observation is not a priority mission for any designated agency at the cabinet level. Not within NASA, the Department of Commerce, the Department of Interior nor any other federal agency. The important technologies that enable us to measure climate change and identify and monitor the impacts to our environment, our lives and our livelihood are the sole responsibility of no one agency or person. Our federal policy and programs are fragmented, even duplicative, and fall short of national goals. Our Earth observation systems that might help mitigate such things as drought or major disasters are neither efficient nor integrated. Consequently our current laws and practices foster dependency rather than enabling risk management, creating expectations that the Federal Government will bail us out of any and all misfortunes.

Who should be the lead agency or position for U.S. Earth observation capabilities? What is our national vision for Earth observations? How are requirements from the federal operational sector such as NOAA, USGS, USDA and EPA reflected in our research and development programs within NASA and NSF? Are requirements from the private sector being addressed?

Leadership is essential to:

- Protect these critical assets;

- Develop a national Earth observation strategy to appropriately addresses climate change and other environmental challenges based on evidence over anecdote;
- Assure economy and efficiency in agency plans and budgets;
- Allow a smooth transition from research to operations;
- Improve U.S. land-observing capabilities to an equal priority with atmospheric and ocean observations;
- Improve capability and cooperation among government, private sector, academia, and non-governmental organizations;
- Assure the much needed integration of our national and international Earth observation systems;
- Develop the products needed to make the best decisions for our country and future generations.

I support the report recommendation that:

> The Office of Science and Technology Policy, in collaboration with the relevant agencies, and in consultation with the scientific community, should develop and implement a plan for achieving and sustaining global Earth observations. Then a single point of contact or program office at the Cabinet level should be established to assure complementary rather than duplicative or fragmented effort for all operational aspects of Earth observation and analysis.

I urge that the private sector—industry, academia, and non-governmental organizations—be consulted regarding an integrated plan for Earth observations through a high-level Commission (e.g., Congressional or White House). Good ideas and best practices abound outside of government.

The U.S. Integrated Earth Observation System (IEOS) would also advance our national capabilities. IEOS would be the U.S. component of the Global Earth Observation System of Systems (GEOSS), which is now supported by more than 66 countries and 46 international organizations. This U.S.-initiated effort is intended to allow federal interagency and multi-national coordination to assure that disparate environmental-related data systems here at home and abroad are inter-operable and compatible. A strong IEOS effort should be characterized by clear designation of responsibilities, enabled by a web-based system of rapid communication, and funded across agency boundaries with a clear purpose. IEOS/GEOSS would improve the capabilities for today's decision-makers by providing new information products. That is not the case today. IEOS has neither been funded nor has program leadership been designated.

We take for granted our capability to use credit or ATM cards almost anywhere in the world. The financial and banking systems throughout the world are inter-operable—they exchange, transfer, translate, and deliver data that is used in decision support tools. If insufficient funds exist, both the bank and the account holder know. Decision support tools used by banks flag and even stop transactions. We should do the same with today's Earth observations systems. Unfortunately, they are not integrated. Our current systems do not allow users to easily access, integrate or deliver data, nor do they include adequate decision support tools. We need a common integrated information architecture that IEOS/GEOSS would require.

Space-based assets made possible the discovery of the Antarctic ozone hole, enabled forecasting more than 40 hours beforehand as to where and when Hurricane Katrina was likely to make landfall, and now help us to understand the evidence and impacts of climate change. These same technologies are used by farmers, energy executives, and coastal managers for their daily operational decisions.

Satellite Measurements for Agriculture and Other Areas

Mr. Chairman, I have generally covered all of the questions in your letter of invitation for me to testify. I submit these additional comments:

1. **Describe the capabilities and applications made possible by data derived from remote sensing satellites. What kinds of measurements are of chief interest to each of the following communities:**
   - **Agriculture**
   - **Natural resource managers**
   - **Municipal water supply managers**
   - **Tourism and recreation officials**

Each of these communities is heavily dependent on accurate weather and climate forecasts provided by NOAA and private sector weather information companies.

Earth observations are widely used for assessments of production and resource conditions at a point in time. We need to move beyond the emphasis of a single snapshot to the incorporation of observations made over time, analyzed by models that can be used to predict yield or resources status as a consequence of future climate, management, biological or societal changes.

According to our U.S. Department of Agriculture, remote sensing associated with sustainable agriculture, forestry, and responsible natural resource stewardship would include:

- Monitoring domestic and foreign yearly yields and harvests of food, and fiber production at field, local, regional and global scales.
- Measuring soil erosion from wind and water.
- Evaluating impacts of global change, especially climate.
- Detecting the presence of, and then monitoring the spread of invasive species including plants, animals, insects and diseases affecting agriculture, forestry, and natural resources.
- Detecting and measuring contamination of soil, water, and air resources, including dispersion of pollutants.
- Detecting indicators of landscape health such as the impacts of resource degradation on agri-ecosystems and natural ecosystems.
- Measuring resources involved in the development and production of biofuels.
- Evaluating the effect on food supplies of agriculture's shift from food production to biofuels.
- Detecting and measuring the impact of, and the progress of recovery from, episodic catastrophic events such as drought, flood, hurricanes, tornadoes, volcanic eruptions, earthquakes and wildfires.
- Detecting the effects of bioterrorism such as plant diseases, water-born pathogens and monitoring progress of remediation.
- Establish metrics for maintenance of soil quality, especially organic matter, and chemistry.
- Detecting and measuring landscape factors indicating compliance with agreements between landowners/operators and federal and State agencies such as the Conservation Reserve Program (CRP), easements, timber sales, rangeland management and public lands.
- Detecting and measuring landscape factors indicating compliance with international treaties and agreements.
- Identifying pathways that transport hazardous waste, and measuring the amounts and ultimate fates of waste.
- Measuring the status and changes of habitat and effects on plant and animal biological diversity.
- Understand the effect of energy development activities on or near critical habitat for threatened and endangered species.
- Measurements to identify and quantify factors influencing water quantity, water quality and air quality.
- Measuring carbon sequestration strategies to determine beneficial climate change.
- Measuring the long-term effects of the increasing removal of ground water from underground aquifers.
- Calculate the near-term and long-term effects of urban sprawl on agricultural production, critical habitat and recreation opportunities.

Agricultural users require direct measurements from hyperspectral imagery to identify ground cover or to the type and health of vegetation and soils, such as too much or too little water, fertilizer or ripeness, on a short time scale of days to weeks. Archived, these same parameters provide climatologists with longer-trend information, from seasonal to yearly variations such as El Niño, for capacity planning such as transportation and silo storage. The Drought Monitor is consulted by farmers, ranchers, and land managers especially in the West, and internationally by those who seek competitive advantage in export markets or where they may gain temporary advantage in their own country or region when drought would decrease our exports into their countries.

Natural resource managers use direct measurement by hyperspectral imagery from aircraft or from space to provide signatures of water resource conditions such as algae and contaminants. These same measurements can provide forestry with tree type and conditions of their health. Measurement of atmospheric temperature and moisture provide input to atmospheric forecast models that predict future temperature, precipitation, and severe weather, which could place healthy resources at risk.

Municipal water supply managers also use atmospheric temperature and moisture measurements to provide input to atmospheric forecast models that predict temperature and precipitation for planning in usage and supply.

Tourism and recreation officials assess atmospheric temperature and moisture measurements to provide input to atmospheric forecast models that predict weather and severe hazards for travel and tourist site conditions.

The World Meteorological Organization (WMO) has recognized 26 Essential Climate Variables (ECVs) documented by the science community—26 measurements that are critical to the models that forecast weather and climate.

NASA, the U.S. Geological Survey, the Environmental Protection Agency, the Department of Energy, the Department of Agriculture, the Department of Commerce and others are developing, deploying, and maintaining Earth observation data sets used in key models and decision support tools.

2. How do these groups gain access to remote sensing data? Is special training required to understand remote sensing data, and if so, how is it derived? Do private companies provide value-added products for these groups?

Groups access remotely sensed data several ways. The NOAA weather and climate forecasting services (National Weather Service, National Hurricane Center) provide data and information through NOAA maintained portals and servers that provide access to over 250 individual information products, including forecasts. Private sector companies (Accuweather, ZedX Incorporated, The Weather Channel) access and exploit this information for individual clients. Commercial companies such as Google and ESRI provide online portals, and consulting and software solutions used by many of the companies to visualize information for several of these markets and to enable modeling and workflow analysis.

Raw remote sensing data by itself is not entirely useful. Training and education vary by the level and sophistication of the end user. Ordinary citizens use data provided through many types of media. Capabilities range from basic literacy skills up to doctoral research, certified professionals and technology aware managers. Special expertise is required to turn data into actionable information. Public domain and general information is provided through government agencies while tailored information for special and commercial users is provided by value-added companies.

User communities throughout the U.S. are generally fairly sophisticated, benefiting from training and information provided by NOAA, NASA, and NSF, the Air Force, and professional societies such as the American Meteorological Society, the National Association of Broadcasters. Individual companies such as ESRI also provide specialized training programs. There are thousands of registered meteorologists and GIS professionals throughout the United States that are trained in the use of the observations and the Earth science models that use them to create trends and forecasts.

The number and diversity of players in the satellite observation field is growing. New and emerging capabilities offered by GoogleEarth, Microsoft Virtual Earth 3–D, ESRI's Explorer and others deliver all types of data and information products to a wide variety of users particularly through Internet-based web services and data portals that allow many users to discover and extract information.

As a cautionary note—we risk becoming too complacent about having imagery and maps right at our fingertips. Visualization is interesting but can be so shallow as to be misleading. Development of good policy alternatives and decisions depend on the quality and configuration of remotely sensed data. Data must be described in terms of metadata, or its appropriateness for use. Compatibility of diverse date sources is essential. The casual user of online free imagery may not realize how much useful spatial and spectral information can come from satellite sensors and used for analysis. The full value of remotely sensed data comes from computer programs and analytical models that extract and transform information from validated and verified sources.

Academia plays a very important role in delivering information products and training. Our universities not only provide vital research, but they are also developing the next generation of scientists, engineers and end users.

We don't just need more data. We need more data that becomes information to enable decisions. The Data was there that said that the nursing home in New Orleans was putting the residents at risk. But the data wasn't available in the right form and wasn't used to make decisions, a tragic outcome for those who needed it.

You as Members of Congress are enabled through a wide variety of information through the Library of Congress that helps suggest a range of policy options that you may use in legislative deliberations.

3. Based on your experience, how broadly are government and industry using remote sensing data to plan and manage crop production and other natural resources?

The most positive potential for government and industry alike is to leverage and integrate information in a complementary way. The most negative potential is for agencies to be fragmented in approach, duplicative in some efforts and void in others.

Both government and industry use remote sensing data to plan and manage many activities including crop production and natural resources. The U.S. Department of Agriculture, for example, benefits greatly from access to a robust set of observations and forecasts that are provided by a wide range of Earth observation systems (public and private). These are used by the Foreign Agriculture Service (FAS) to provide the monthly global crop assessment products. These products are key to policy and management decisions on agriculture worldwide. Business entities that advise the agriculture community are critically dependent on NOAA and other sources of near-term weather forecasts and seasonal to inter-annual forecasts of climate conditions that are used in decisions of what to plant, when to plant, and when to harvest.

NASA's MODIS satellite has been an invaluable source of information to detect and fight wildfires in the West. Knowing where the active fire lines are helps protect the safety of our firefighters. The sensors help scientists monitor the extent of irrigated agriculture and deforestation worldwide and provide data that private analysts use to predict the global agricultural production including which crops will be in short or over supply.

As industries become more dependent on managing on small margins or managing against disaster risk, information from remote sensing will become even more important. Weather risk managers seek to identify the economic consequences of adverse weather on enterprises and organizations by relating their revenues, margins and costs to critical weather variables. A professional market exists that makes its business in assuming this weather risk. In exchange for a premium or other benefits, these businesses take on this risk based on indices of pertinent weather variables, such as average temperature or rainfall.

A couple of years ago, the Metropolitan Area Planning Agency representing sixty-four member organizations from five counties in Nebraska and Iowa contracted to provide aerial data acquisition, digital orthophotography, and production services for over 2,200 square miles in Nebraska and Iowa. It was a multi-sensor program involving a large consortium of government user communities. It included a combination of Lidar mapping, floodplain mapping, data for master planning, design and construction projects, floodplain analyses, web services, highway and road design, 3D visualizations, GIS municipal requirements, and various engineering and public works functions.

There is similar interest in managing the economic impact of extreme events—earthquakes, hurricanes, monsoon and typhoons—by utilizing indices based on windstorms, seismic magnitude and seismic intensity in ways that are very similar to the way the weather risk market uses weather data. The risk-management business has strong interest in serious, systematic attempts to improve, expand and intensify the capture of data relating to our planet. We also see growing interest in the risk management and insurance industries for understanding shorter-term weather risk in terms of climate change. In sum, better, fuller data mitigates data risk and model risk for the providers of risk capital.

Moving Forward

As noted earlier, the American people deserve the best and most comprehensive information about our changing planet. Recent revelations about climate change, particularly as affected by human activity, elevate the importance of ensuring national climate observing systems. We must approach our environmental security with as much rigor and commitment as we approach homeland security.

We should build upon the Decadal Study results by:

- Ensuring that the U.S. long-term climate monitoring capability is maintained;
- Addressing the void in Earth observation leadership and vision;
- Establishing a single point of contact or program office within the Office of Science and Technology Policy;
- Improving our research-to-operations efforts across all relevant agencies;
- Establishing a common integrated information infrastructure;

- Implementing the U.S. Integrated Earth Observation System (IEOS) of the Global Earth Observation System of Systems (GEOSS);
- Immediately beginning a dialogue with the private sector—industry, Academia, and non-governmental organizations—to ensure our satellite observation assets respond to the needs of various sectors as well as to consider new technology solutions, such as the Geographic Information System for the Nation described in Appendix A.
- Establish a high-level Commission composed of private sector (industry, Academia, and non-governmental organizations) representatives to further examine and develop an integrated plan for Earth observations.

Appendix A

A Vision for a National Geographic Information System

By Jack Dangermond, President, ESRI
Redlands, California

Background

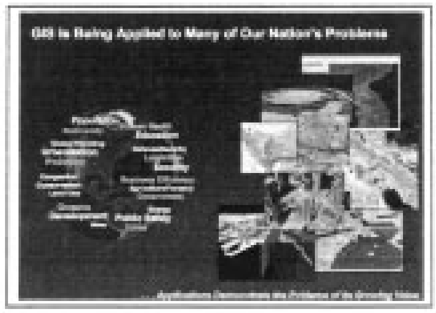
Geographical maps have been a critically important tool for human beings for hundreds of years as we explored, traveled, inhabited, fought over and planned the territories of our earth. In the United States maps have become an essential part of the public, private and not for profit planning and execution efforts at the local, state, federal and international levels.

Maps tell us where we are. They help us understand our surroundings. They help us draw ideal routes from here to there. With knowledge and wisdom maps can be a means for human beings to settle disputes; with ignorance maps create conflict. Maps can convert the unknown into the known making it much easier for us to answer the question: What should we do?

As with every other walk of life, maps have been transformed by computers and advanced communications systems. In the old days maps were line drawings; today maps are data. Today maps are built with GIS technology, remote sensors, complex algorithms, and story telling. The declining cost and capability of storage, processing and dissemination has made it possible to build maps with nearly unlimited amounts of data and analytical capacity.

Two parallel and related developments have proceeded from this change. First the quality, efficiency and productivity of government actions have improved. Second, a new profession – GIS architect – has emerged to provide tens of thousands of good paying private and public sector jobs as new businesses have sprung up to create new products and services that take advantage of GIS's extraordinary utility to human endeavors.

Today, at the Federal level the US Government makes considerable use of digital map data and GIS technology in nearly every department ranging from emergency management and national security to environmental science, conservation, and human health. These applications and their many benefits are well documented and continue to grow. Historically, many of these GIS applications have been project focused and related to single missions. However, as cities, counties and states have increased their usage of GIS there is an unmet need to develop a more comprehensive enterprise approach and national system.



Such a system would integrate the management of the nation's key geographic datasets and support various government agencies with geospatial services and applications. While there have been many excellent efforts, they have fallen short of anything resembling an operational system.

An Integrated National Geographic Information System (GIS) is possible. Today's enabling technology--software, hardware and networks make it possible to consider the creation of a GIS for the nation. Such a system would provide a comprehensive and authoritative description of our nation's geographic knowledge. It would also be used jo support a host of federal applications such as emergency response that requires cross cutting geographic information coming from multiple sources. The information in this system would be maintained by existing on-going business processes across existing government agencies and integrated periodically by a special organization in the federal government.

A nationwide GIS would include:

- A series of standard geographic datasets (framework layers) that are systematically organized in data bases and made available for supporting many applications (i.e. in government, academic settings, and the private sector). Some progress has clearly been made at the federal level at defining, building and assigning responsibility for managing some of these key framework layers.
- A series of workflows that would transactionally maintain (update) these datasets as part of various on-going government workflows. The concept here is that the national GIS would be maintained directly through participation and collaboration with existing government agencies. The system would integrate information from many sources and authors – using standard data models. The result would be a standardized, harmonized and consistent body of knowledge for the country.
- Data management responsibility (governance) for the data layers would be organized by the federal government but managed by the most capable organizations, i.e. federal, state and local government agencies and in some cases, the private sector (imagery, roads).

- A suite of applications that leverage (use) the geographic information in a host of mission areas including operational, planning, reporting, decision making, and policy guidance.

- A stable organizational and political environment is needed. Key to the long term viability of a national GIS will be the creation of a centralized organization that is mandated to provide an integrated GIS system and maintain it.

- Leaders and liaisons working full time on collaborative efforts and partnering. These individuals would create collaboration partnerships between and among all levels of government and private industry. While most government agencies are willing to informally share their data sets, their willingness to participate in a collaborative and inter-dependent system will require the establishment of a centralized organization with funding, leadership and the ability to provide benefits back to participants. Bottom up approach for data sustainability, funding down data up.

Implementing such a system would require:

- A common geospatial data model (based on multiple application requirements and community agreement). This model would be used in every city and county in the nation and also be the basis of a national system.
- Data management workflows implemented within different organizations for maintaining (via transactions) the different layers of data. This should initially be developed in a series of case study cities and continuing work in collaboration with regional governments.
- Enterprise system architecture based on modern web service standards and implemented in a distributed environment. Implementation would involve a series of distributed subsystems organized around specific business processes (i.e., water resources, geology, transportation planning, etc) and specific geographies (i.e. states and regions).
- Technical and management leadership – geospatial professionals who can design and manage. Leaders who can transform the vision into action and develop a plan to sustain and maintain systems.
- A strong legislative mandate and an organizational framework.
- Funding for implementing and maintaining such a system. Such funding should probably be centralized (Federal Government) and where possible, require matching participation from partners (existing federal programs, and state and local government). Local government must receive consistent funding from state and federal for maintaining critical framework data, which then gets supplied to state and federal as part of a national plan.
- Local governments need to maintain the most detailed GIS layers with accuracy and scale to serve local applications. This same data would be resampled or generalized for state and federal use. Minimizes duplication of effort.
- Funding and support will be required for rural/unincorporated areas with no GIS capability.

Steps for designing, building and managing a National GIS would include:

- A broadly accepted vision of national needs for a GIS needs to be developed. This vision should include the key application areas and information products, as well as the necessary resources that will be required to build such a system (i.e., people, technology, databases, organization, collaboration, funding, etc.).

- A strategic plan should be formulated. The government should hold a series of short specialist meetings to discuss and establish the key issues, opportunities, and solutions for developing an operational system. This should bring together the most capable people in the nation to help define and address the key requirements. Participants should include GIS professionals and policy makers who have experience in designing and implementing large programs and operational systems of this type. This should be headed by someone who has facilitated sessions of this kind before.

  The primary result of these meetings should be a strategic plan. The plan should include vision, architecture, tasks, timelines, responsibilities, and priorities. The plan should be peer-reviewed by individuals with the eye on refining the plan with real application services.

- Sell the strategic plan to policy makers. This means clear definition of the program and its benefits to individual agencies and the government as a whole. This must lead to enabling legislation outlining the mandate and how the program is to be implemented (i.e., organizational structure, operating plan, and budget across government, etc.).

- Develop a specific plan. This involves creating a more specific architecture and organizational/institutional structure for implementing the national system. This plan should be done by GIS system architects who have actually engineered and implemented major, successful systems.

  The specific design should be based on a clear definition of critical information products and services that would be generated by this system. While it is not necessary to develop a comprehensive inventory of all outputs, an attempt should be made to lay out those priority products that are representative and considered most critical.

  These outputs (together with their metrics of use) should be used to help drive the data model, applications, system architecture, and ultimately the structure of the organization that will manage the system.

- Widely review the plan with the objective of refining the system and building a broad community of interest across the geospatial field – "Harnessing an army of people to work on all aspects of the system".

- Implement the plan rapidly. The system should be implemented by using a prototyping methodology with a series of small incremental efforts that are short in duration, and focused on producing high value information results. This effort should be led with a motivated and experienced team working closely with various government partners and private sector organizations.

- The system should generally avoid new research efforts, however, for complex problems, a series of specialist meetings should be held to define and provide guidance on specific issues with a view of discovering solutions. The results of these meetings should be identification of key areas for further research within universities and other organizations.

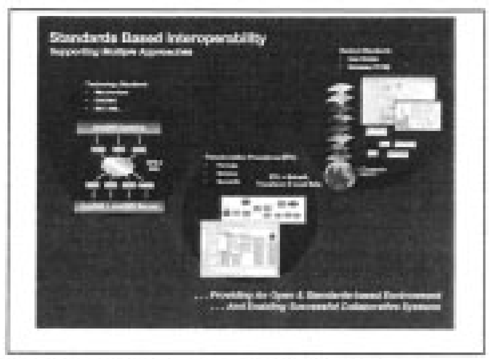
Data integration challenges

One of the biggest challenges for a national GIS involves the integration of data being created and maintained in multiple organizations. These challenges stem from the fact that traditional agency specific data sets have typically been developed independently, to support focused missions (i.e., soils for agriculture, hydrology for water resources, etc.). This often means that data may not necessarily have been designed to integrate with map layer data from other sources. While geography provides the geospatial framework for integration, many subtle integration issues arise when maps are overlaid (i.e., semantic and geometric inconsistency). Also there are issues related to data resolution, accuracy, scale and differing techniques originally used for data collection, etc.

Solutions for overcoming these data integration problems

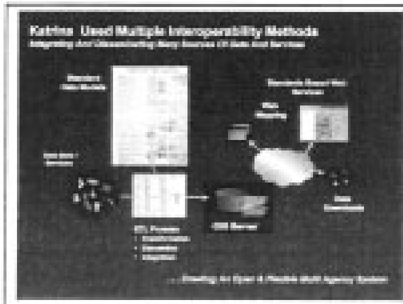
Create common geographic data models. Further complicating this context is that for certain datasets it will require blending (harmonizing) a mosaic of state and local datasets into national layers (i.e., cadastral data). This is technically and scientifically possible, but for a variety of reasons (largely due to organizational structure, budgets and mandate), has not been attempted at the national scale.

Perhaps the most critical things to be done are the creation of a widely accepted set of integrated data models that would be used at all levels of government. If this were widely accepted, the scientific issues of data integration would be minimal. These models need to become standards by the federal government and linked to various funding programs across the nation. Also, they must reflect the various missions and uses by all levels of government. Finally, they must work together as an integrated model of geographic reality.



Computer techniques for integration of heterogeneous data is possible

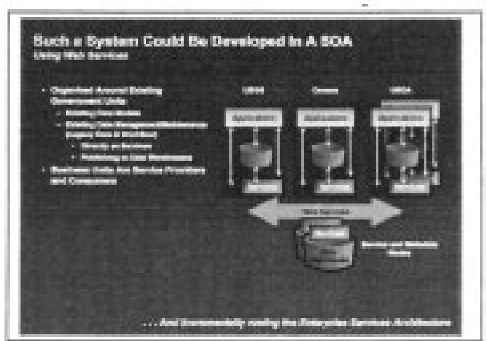
In the short term, a national system should be developed that mosaics the existing state, local and federal data together using a common integration model. While limited, this is possible and, in the past few years, has been used extensively. This process is known as Spatial ETL and involves Extracting, Transforming and Loading of data layers from multiple sources into an integrated data base using a common semantic data model. This has been done successfully in various pilot projects under the direction of DHS and NGA. Examples include "Project Homeland" for San Francisco bay area and the state of Colorado, as well as the GIS for the Gulf project for areas affected by Hurricane Katrina).



Technology
This project should be viewed as an enterprise IT system – not a research project for developing new technologies (i.e., hardware, GIS software, etc.). Whenever possible, the system should be built using proven COTS products. There are now multiple vendors that provide standards-based technology that is designed to solve the problems of building a national GIS.

Standards and architecture
Modern GIS server technology together with open standards and Services Oriented Architecture (SOA) can provide enabling components for implementing a national system. This architecture can support an integrated system that distributes the ongoing management of geographic subsets in a distributed network of participating nodes, making it possible for federal, state, and local organizations to collaborate in the maintenance and use of a national geospatial database.

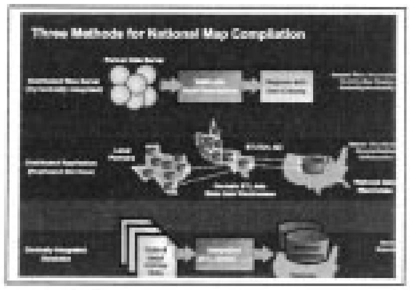
At the same time, this type of architecture supports easy integration with other IT systems and crosscutting applications such as those required for responding to national emergencies.



<u>What will it take to create a National GIS mandate for the country?</u>

- Leadership (i.e. a person people follow who can implement such a system and that the people will trust, empower, and follow).
- Demonstrated ongoing action as sustainability of data is critical.
- A clear <u>definition</u> and program <u>plan</u> of what a National Map/National GIS must be.
- A mandate supported by leadership (USGS, DOI, OMB, Congress…).
- Improved communication. Effective communication is needed not solely about the system vision, but also the implementation plan, status, and results).
- Collaboration and compromise across all levels of government. These efforts should focus on minimizing duplication of effort where possible, so it is easier to maintain and sustain data.
- Resources (people, fundraising, advocacy and education, etc.).
- An operational organization.
- Funding and simplified procurement process for inter-government collaboration.
- Better understanding by policy makers of the benefits of GIS.

<u>A national GIS system should be collaborative – a network of partners.</u>
Clearly, a national system must take advantage of state and local governments, as well as commercial data partner resources. In the past, virtually all geographic data used by the federal government was created and maintained within the federal community. Today, for selected data types, state and local government GIS's create significant amounts of geographic data that is as good as and often better than collected by the federal agencies. By developing the right partnerships as well as data standards and integration processes, the federal government could take on a new role of periodically integrating and making this data available as national coverage's for use by everyone. Also, for selected data types (i.e., street centerline data, imagery, etc.) the private sector is now offering reliable high quality data that can be licensed at prices that are considerably less expensive than traditional in-house government processes. These resources should be capitalized on.



Federal Government Role

Beyond the development of the overall system, there are two significant roles for the federal government to play. For certain layers, the federal government is the only authoritative source (i.e., geodetic control, hydro, networks, elevation, etc.). These datasets must be maintained on an on-going basis by the federal government.

There is also a need to create, set up and manage an integration process that integrates the data from many sources. The federal government needs to set up a program and system for creating this ongoing integration infrastructure. This will require the right kinds of partnerships related to data sharing and access and also a program for ongoing funding.

Finally, it will be necessary to set up a technology and organizational support infrastructure for hosting the National GIS in a high performance and reliable environment. This infrastructure would not only be the initial data services infrastructure, but also serve as a platform for the wide array of applications supporting the federal government. It would also provide a continual repository where anyone could go to get copies of the data for various uses.

Conclusion

The world of geospatial data and applications is progressing rapidly. US federal agencies and other governments around the world are continuing to discover the rich benefits of using GIS as a framework for improving government services. A national approach for improving and integrating geographic data in the US is clearly overdue. Successful application in the fields of public safety, national security, emergency response, water resources, human assets, agriculture and the environment will provide the evidence that a national GIS strategy would bring many benefits. Government agencies must be encouraged to work together to realize this common goal.

Some may perceive that the reason a National GIS program has not gone forward in the US is because critical research or technology elements are missing. This is not the case. There are many large, successful operational GIS systems that have been implemented and are working quite well. There are countless examples of successful operational systems at all levels of government as well as in the private sector.

Today, the critical issues involve organizational mandates, leadership, and financial resources. The development of such a system is complex and will require good design, a strong leader, and organization with ongoing funding to make it viable.

BIOGRAPHY FOR JAMES GERINGER

- Native of Wheatland, Wyoming.
- B.S. in Mechanical Engineering from Kansas State University.
- Veteran of 10 years active and 12 years reserve in the U.S. Air Force.
- Worked as project officer to launch several space based satellites for the unmanned space programs of the Air Force and NASA, including the Global Positioning Satellite System, remote-sensing early detection/warning systems, the Interim Upper Stage for the Space Shuttle, the Mars Viking Lander, activation of the Peacekeeper missile system and disaster recovery from nuclear, biological and chemical warfare.
- Served in the Wyoming Legislature from 1983 to 1994, including six years each in the House and the Senate. Committee chairmanships included Appropriations, Judiciary and Management Audit.
- Contract administrator for the construction of a 1700 megawatt coal-fired electric power generation plant near Wheatland Wyoming 1977–79.
- Went into full-time farming in 1980, continued through 1994.
- First elected as Wyoming Governor in 1994, reelected in 1998, completed second term in January 2003. Focused on improving education through standards, accountability and technology, modernized economic planning to extensively include technology, changed how natural resource agencies among State, Federal and local governments worked together, implemented strategic planning tied to performance based budgeting and upon leaving office, provided Wyoming state government with a budget surplus, one of very few states to make that claim early in 2003.
- Emphasized community based solutions particularly for health and social services and promoted the use of consensus building to resolve difficult issues.
- Past Chair of the Western Governors' Association.
- Chairman of the Education Commission of the States.
- Served on the GeoSpatial One Stop Board of Directors, National Commission on Mathematics and Science Teaching for the 21st Century, the National Commission on Service-Learning, the National Commission on Teaching and America's Future, Chair of the National Governors Association Technology Task Force and as charter member and current Chair of the Board of Trustees, Western Governors University.
- Current memberships: Mapping Sciences Committee under the National Academy of Sciences National Research Council; Western Interstate Energy Board; Association of Governing Boards for higher education; Operation Public Education; the Board of Governors of the Oquirrh Institute; and, Co-Chair of the Policy Consensus Initiative.
- Joined Environmental Systems Research Institute (ESRI) in the summer of 2003 as Director of Policy and Public Sector Strategies, focused on how senior elected and corporate officials can enable productivity through technology more effectively in business and government. Primary responsibility is to facilitate development of a policy for a decision support system for national location based information integration. ESRI, the world leader in location based software and applications, is headquartered in Redlands, California.
- Recent keynotes include presentations on health care, health data standards, alternative energy, education policy, natural resources, homeland security, the importance of government services enabled through Internet portals, web-based infrastructure, e-government planning and sustainability of Earth's resources.
- Received the National Association of State Chief Information Officers (NASCIO) 2004 National Technology Champion Award.
- Governor Geringer and his wife Sherri have five children and ten grandchildren. They reside in Wheatland, Wyoming, the site of ESRI's newest satellite office.

DISCUSSION

CONSEQUENCES OF EARTH OBSERVATION DROP-OFF

Chairman GORDON. Thank you, Governor. And those were good recommendations that we certainly want to put in the mix. Thank you for that real-world suggestion.

Dr. Moore, as you showed us this—the budget, it demonstrates that, really, these systems have been hit with a double-whammy. One is the reduction in funding and secondly, just the ineptitude at NPOESS. It is, you know—the waste of money there is so disheartening. It—this—that is a major priority for this committee under Chairman Boehlert, he did his best to try to get a handle on that, and I don't think that we got good information, and he—I think he would concur with that.

I have talked both with the Secretary of Commerce as well as the President and CEO of Northrup Grumman. They tell me they are on top of this now, and it is going to be our priority. And so I hope we are going to see it brought back into line.

But let me—what I would like to ask you about is you mentioned there were 17 replacement missions, although none of those are in the budget for 2008, and it is—if history is any lesson to us, it is—certainly, I think we can assume that all 17 won't be in the future, and very possibly, none.

So can you tell me—can you break that down in terms of what we are going to lose in terms of just status quo if we don't have these 17 missions versus what we are going to lose in terms of keeping up with the state-of-the-art?

Dr. MOORE. Yes. Congressman Gordon, let me first agree with you that circumstances we face today are the result of a perfect storm. A decline in the NASA budget and then the failure on the NPOESS leave us in a very precarious position.

What are we not going to have?

We recommended earlier in our—early in the study, for the early phase, an ICESat follow-on—the ICESat mission failed. There were difficulties. And yet we know the ICE measurements are one of the critical measurements as we look at the question of climate change. The Earth radiation—this is fundamental to any climate model. That was descoped off of the NPOESS system. And so now we are vulnerable.

I think the issue of carbon sources and sinks, there is a mission that is being developed, the Orbiting Carbon Observatory. But it is sunlight-dependent, and it must operate in a very clear sky. When you don't study the carbon cycle, the sources and sinks, because of photosynthesis, adequately with a sunlight-dependent mission. So we have to have a follow-on that uses lasers. That is not in the budget.

The issue of hyperspectral, for instance, in determining disease outbreaks, this is something we have tried to achieve for a number of years. That is not in the budget.

Air pollution modeling—monitoring, that is not in the budget.

And I want to go back to one thing that we mentioned earlier. All we have to do is to get back to where we were. And so as a percent of GDP, as a percent of the NASA budget, as a percent of household income, that would be lower in the future than it was in the year 2000 and the year 1996. At that time, this country thought that these measurements were important, and we have just gone down this slide. And I think that the extraordinary thing is we can achieve this robust program if we could just simply get the budget restored back to where it was in the year 2000.

Chairman GORDON. Thank you.

Governor, do you endorse this proposal?

Mr. GERINGER. Chairman, yes, there are several features of this proposal, in particular, the ones that call for innovation and creative approaches, and a formal planning and program office, such as through the OSTP, to pull everything together to consolidate a vision, in a practical way, put a process together to where it could be administered to phase it and make it work.

Chairman GORDON. And Governor, as a Republican western governor, who, as you say, has seen this up firsthand, could you, again, tell us what you think if—you know, we have all seen the ad about pay me now or pay me later. I mean, in terms of money, public and private dollars, in terms of suffering of folks, just at least in Wyoming and the west, what is your opinion of what kind of price are we going to pay if we don't do this?

Mr. GERINGER. Well, the price you pay is tough to quantify, but in terms of just what we enable other people to do, I guess my focus would be on not the dollars that are spent but the frustration of individuals who know what they could do if they had the tools and the information to make decisions, to manage the risks, to make their own business work.

Now we have five children, 10 grandchildren. They are all interested in what they might do. And instead of expecting a job, we would like them to go out and make a job. Well, how do you make a job if you don't know the information required to plan your industry, to manage the risk, and to understand the marketplace? And the marketplace is driven by a lot of external information, particularly derived from satellites, such as this. So it is—the cost is beyond dollar amounts. It is just in our ability to enable the next generation.

Chairman GORDON. Thank you.

My time has expired.

Mr. Hall.

PRIORITIES AND RECOMMENDATIONS OF DECADAL SURVEY

Mr. HALL. Governor, the Decadal Survey, as you know, recommends an increase of $500 million per year in NASA's Earth science budget to implement the Survey's recommendations, but we are told in what we hear and what we read and what seems to be every—almost everyone's understanding is that we are not likely to see that large an increase in NASA's budget any time in the near future.

Given the limited funding situation, which of the missions recommended by the Decadal Survey do you believe are the most important for the Federal Government to implement?

Mr. GERINGER. Chairman—Congressman Hall, the—I don't know that I would pick out any one, but I would pick out an approach, I guess is the best way to put it.

The recommendation, and this is not a mission in particular, but it is a recommendation where the—where OSTP pulls together everything, I think, is one of the lowest costs and probably a very significant cost-avoidance recommendation. So we can put together a plan to achieve and sustain. I think the first concentration needs to be on to sustain what we expect to be out there. Look at the predictive capabilities for today's storm here in DC. If we lose that capability, I can't imagine what would go on outside your doorstep here.

The other things, and Dr. Anthes and I were talking earlier about GPS systems, the Global Positioning Satellites that are up there that can be used with suborbital sensors to detect changes in the atmosphere, major density. It is a relative low-cost mission that could be accomplished with existing satellites complemented with a marginal increase in funding.

I particularly like one of the recommendations that says that the three agencies, principle agencies, NASA, NOAA, and USGS, should pursue innovative approaches. I think we need to cut them loose and let them pursue some innovative approaches. That is one of the things that has always benefited our economy and our competitiveness. Let us not be so rigid. Let us get them the tools, the ability, and the funding to make it work in creative ways.

Mr. HALL. I will ask one other question of Dr. Anthes.

You made the statement that I agree with. You said we want to get back to where we were. And we are in the second month of that this year of wanting to get back to where we were prior to the November election. So I am going to—I think you made a good statement. You must be a Republican.

IMPROVEMENT OF WEATHER FORECASTS

Seriously, let me ask you this. Explain to us, with some kind of concrete example, how the missions recommended in the Decadal Survey is going to improve weather forecasts. And are we talking about more accurate predictions, longer-range predictions, or some other type of improvement——

Dr. ANTHES. Thank you very much——

Mr. HALL.—to get back where Dr. Moore says we ought to be?

Dr. ANTHES.—Congressman Hall.

I was referring to the non-partisan state of Earth observations——

Mr. HALL. Okay.

Dr. ANTHES.—just for the record.

I appreciate that question.

I think this gives me an opportunity to talk about what we need is a system of observations. It is not—we don't have a silver bullet out there to improve weather forecasting. It is very much like when you go to the doctor for a check-up, you don't just ask—he doesn't just ask you—or she ask you how much you weigh or how tall you are or what your blood pressure is or what your cholesterol level is or how fast you can do a treadmill or what your heart condition is or your lung condition is. You need to know all of these things about the body. So you need many different kinds of observations, if, number one, you are going to understand the health of the body, and number two, if you are going to make any kind of projections about what your prognosis is for the future.

So weather forecasting is kind of like that. We don't need just temperatures in the atmosphere or just ocean temperatures or just winds or just cloud cover. We need it all, because they all contribute independent information.

So what we are suggesting is this balanced set of recommendations, which includes winds, temperature, water vapor, ocean temperature. These are going to improve all aspects of weather forecasting from the two-week forecasts—by the way, I did a hearing at the Senate just a week ago. When I got back to the hotel, I looked at the long-range forecast, and I said to my colleagues here, "Tuesday is going to be a big storm event in the east. Watch out." That is a—seven days in advance, and that is not bad. We stand to lose that capability if the present trends toward observations—loss of observations continue.

On the positive side, we are not anywhere near the limit in predictability, what we could do. Look at Katrina. Katrina, a wonderful forecast, but that was unusually good. We need to get every hurricane forecast hitting—heading for the Gulf Coast, the East Coast with that accuracy.

So it is not just a negative thing about forecasts getting worse if we don't get more—if we lose observations that there is a positive benefit here of getting a balanced set of observations and improving our forecasts of tornadoes, hurricanes, extending the warnings of severe events, and right into the interseasonal variability of climates, including the droughts that the Governor talked about.

Mr. HALL. How long would it take—excuse me. Is my time up?

Chairman GORDON. It has, but, sir, you go right ahead if you need——

Mr. HALL. I just wanted to ask a follow-up. How long would it take the average citizen, with all of those types of tests that—all of us can understand any of them individually but not all of them together. How long would it take until the natural—the average citizen would see these improvements in daily operational weather forecasts? And if accuracy is your main thrust, what about the long-range, the timeliness of it?

Dr. ANTHES. Well, forecast improvements have been gradual, and they will continue to be gradual. So the—but what happens is the humans' expectation grows as the accuracy gets better. So what we take for granted now as a three—as a good three-day forecast, we are now expecting that at six days or seven days. And so the expectations rise as the accuracy rises.

However, people who really look at this and depend on it for an economic living know. They keep track of the scores, accuracy increases and such, because they are making decisions based on probabilities. And so the people who really need it to make quantitative decisions are doing this right now.

For you and me, the public, it will be so gradual, it—you know, you will wake up 10 years from now and we will have good two-week forecasts instead of good week forecasts.

So it is gradual for the public. It is very valuable and well monitored for the decision-maker.

Mr. HALL. I thank all three of you.

Yield back.

Chairman GORDON. The gentleman's time has expired.

Mr. Udall is recognized for five minutes.

Mr. UDALL. Thank you, Mr. Chairman.

I wanted—I want Judge Hall to know that we always take him seriously.

DETAILS OF DECADAL SURVEY RECOMMENDATIONS

I did also, in the Decadal Survey recommendations, note that there were over 100 proposed missions, and you all distilled it down to 17, with the idea that they are integrated. And I am sure there were some tough trade-offs there, but I think it is important that the Committee understand that and the general public that this is not just a wish list. This is a very focused effort to identify where we would have the maximum return on our investment.

If I could, in that spirit, I wanted to talk about the opportunity cost to explore that if we do not maintain a robust Earth-observing system. And as I understand it, we need continuity in Earth-observing data over long time periods to improve smaller-scale regional climate projection models. And it seems to me that we are going to need better regional information that would allow us to be better prepared for changes in climate that are likely to occur, even if we stabilize greenhouse gas emissions.

And then also, if we—and I shouldn't say if. I want to say when we adopt measures to limit greenhouse gases, we will need to verify that the measures we adopt are, in fact, resulting in reduced emissions and lower concentrations of greenhouse gases.

So what role would the Earth-observing system you are proposing play in fulfilling those needs? And is it going to be more difficult to—or take longer to accomplish these two things without an Earth-observing system?

Maybe start with Dr. Anthes, and then Dr. Moore, you could follow on.

Dr. ANTHES. Well, that is a very excellent question. And the programs that we are proposing—first of all, it is a really good—you noted that we went from over 100 proposed missions to 17. And one of the criteria we had for prioritization was that it had to be affordable.

The second point is it is a balanced program. It supports climate as well as weather. It supports industry, agriculture, water management, as well as science. And so the program we are proposing is an integrated set of observations, and we think we need them all for exactly the reasons that you iterated.

Mr. UDALL. Dr. Moore.

Dr. MOORE. Let me just draw attention to three points.

First of all, as you note, stabilization of greenhouse gas emissions is going to be a very real challenge, but a challenge we must meet. Stabilization of emissions does not lead to a stable concentration in the atmosphere. Stabilization of emissions is a step towards stabilizing the concentration of the atmosphere. But stable emissions will only lead to a constant growth of CO_2, for instance, in the atmosphere. So that means that we have to face this question of climate change head on.

One of the missions that we recommend for the early timeframe focuses on soil moisture. Soil moisture is, perhaps, one of the key ingredients in climate models as well as in terms of what is really important to the people who live based on—in areas based upon agriculture. But it also means that if you live in an area that is a flood plain. So I—that is a key issue.

And the third is that the kind of missions that we recommended, for instance, on CO_2 where we looked at sources and sinks of carbon dioxide. Any kind of management system of greenhouse gases is going to require the knowledge of what are the sources and sinks for carbon dioxide. It is fundamental.

Mr. UDALL. Chairman Gordon, I know the clock isn't running. I am assuming I have got a minute or two left. Or I should say the lights aren't working.

ADDRESSING EMERGING REGIONAL AND GLOBAL CHALLENGES

Chapter 2 in the report lists six emerging regional global challenges. To mention two of them, changes in natural systems due to climate change and the role of ice sheets and the sea level rise, and there are four other identified challenges.

Can we address those challenges if we don't maintain an Earth-observing system? And maybe you could provide an example or two that would illustrate our ability to respond to these challenges would be limited by the lack of information from Earth-observing systems if we don't have those up in place.

Dr. ANTHES. Well, there is—we could all probably come up with many examples. Let me just give one.

Sea level rise is one of the most important issues facing society, particularly in the next generation and the generation after that. For many years, the models of glaciers indicated a relatively slow melt of the Greenland ice cap. But just in the last few months and years, through measurements, very precise measurements of the Earth's gravity field, we could tell that the—Greenland was losing mass at a far faster rate than the models of ice melt would indicate. And what apparently is happening, and I am not a glaciologist, so bear with me, but apparently, it is the—water is running down and causing slippage of the ice off the continent, and perhaps a much faster rate of ice melt than we were predicting a few—even a few years ago.

So if we suddenly stop measuring the Earth's gravity or suddenly stop measuring how fast the ice is melting, we don't know whether that is an anomaly, you know, that happened to be an anomaly over the last couple of years, a rapid ice melt and is going to go back to a slow melt, or it is going to continue to accelerate.

And so what we might be thinking is 100-year problem might suddenly become a 25-year problem. We don't know. But these are the kinds of questions and—that we really need to stay on top of, because we are going to have surprises.

Chairman GORDON. Thank you, Doctor.

The gentleman's time is expired.

Mr. Bartlett is recognized for five minutes.

ENVIRONMENTAL DATA AND ETHANOL USAGE

Mr. BARTLETT. Thank you very much.

As you probably have noted in the papers, our zeal for producing ethanol has driven the price of corn from $2.11 a bushel in September to $4.08 a bushel in December. This is very likely, I think, to encourage farmers to take lands out of agricultural reserve, most of which lands shouldn't really be farmed, which is why they are in there, but $4-a-bushel corn is going to be a big incentive to take those lands out of the agricultural reserve and put them into production.

There are other reasons for being concerned about the use of fossil fuels. But if we limit ourselves just to the environmental effects, clearly, we need to understand the environmental effects of CO_2, and we do, but there are also going to be big environmental effects of taking these lands out of agricultural reserve and putting them into production.

My question is how much will our decision-makers lose in quality data for making decisions to how we need to move in the future relative to this ethanol thing if we don't have the additional programs that you all are encouraging?

Dr. MOORE. This is an area where I want to compliment NASA. It does appear that the increase in 2008 and 2009, which is an increase of a downward trend, is to essentially address, as I have mentioned in my testimony, the precipitation mission and the Landsat. The Landsat satellite system will be fundamental in monitoring agricultural regions, absolutely fundamental. You need the high resolution if you are to determine what type of crop is growing. And so this whole issue of biofuels will be very dependent upon the Landsat system. For that, I think that NASA is doing a good job at getting it back on track.

Mr. BARTLETT. Our public policy people are going to be caught on the horns of a dilemma. Clearly, greenhouse gases are implicated in the increase to Earth's temperature. And that is a big environmental concern. But all of life on Earth is dependent on about the upper eight inches of topsoil. If you can't grow food, you are not here. And as we take this land out of reserve and put it in production, we are going to be losing more topsoil. And so our policy-makers are going to be faced with a tough decision. Do we save our topsoil by increasing CO_2, which is the greater of those two evils? And my concern is that we will need more, not less, information for making those decisions.

And I would just like to get on the record my concern, and the concerns of a great many people, that there are two environmental concerns here that are kind of intentioned. And, you know, which way are we going to go? And I think that will be largely dependent on the quality of the information we get.

And so in a very real sense, this is more than just an academic exercise. It will affect each one of us, not only by the quality of the air we breathe, but potentially, by the volume of crops that we are able to grow.

Mr. GERINGER. Mr. Chairman, let me—I think it was more of a statement than a question, but let me respond anyway.

You asked what would happen.

One of the things that agriculture uses, one thing that a governor uses is as much information as it can. Having been in politics for a number of years, I am struck by how, in the absence of information, we make decisions anyway. Anecdotes serve us well, don't they? It is easier to make a judgment based on an anecdote from a story back home, absent any other information.

So now let me turn it around and say if we had better information, such as what Landsat-5 and Landsat-7 started but are not going to continue, and certainly the granularity and the detail that we need today just to make individual decisions in agriculture production for individuals and then to take that beyond and say what has been the impact of increasing ethanol or other renewable fuel production as an offset to, say, food supply or the loss and erosion of topsoil? What are the practices that happened? How do we know that they are happening, other than anecdote, if we don't have a broader view that only satellite imagery can provide, as well as ground-based information?

So you need a combination. We are not going to be able to even evaluate the shift of production from food to fuel if we don't have the sensors in place.

Chairman GORDON. Thank you, Doctor—Governor, and thank you, Dr. Bartlett.

Mr. BARTLETT. Mr. Chairman, I know my time is up, but I would like unanimous consent to submit a question for the record, if I——

Chairman GORDON. Certainly.

Mr. BARTLETT.—might.

Chairman GORDON. Certainly.

Mr. BARTLETT. Thank you, sir.

Chairman GORDON. Dr. Wu.

Mr. WU. Thank you very much.

And my mom always wished I had finished medical school, and I have been upgraded. And I am going to tell her about this.

Thank you very much, Mr. Chairman.

First just a—drop-out is such a harsh word. I am on a leave of absence from my medical school, which has now gone on for approximately—well, we are approaching the end of the third decade.

Chairman GORDON. Of course, that was after getting a law degree, too, so——

Mr. WU. And I am told—I am sure that if I just admitted my dire mistake, they would let me back in, because the admissions committee there never makes mistakes.

WEATHER PREDICTION

But first, just a question of curiosity, for you gentlemen.

A meteorologist friend of mine said years ago that at five days, the forecast is random. You might as well just, you know, just throw it against the wall, but that was a few years ago. At what point does your forecasts or any meteorologist's forecasts just kind of go random these days? And I am just kind of curious.

Dr. ANTHES. Well, that is an excellent question.

Years ago, there was some theory done on non-linear systems, which said there was a predictability limit of about two weeks. That was the theoretical limit. That is after two weeks, things were deemed random.

We may be a little longer than that, but that is still the order. We don't see what we call the typical weather forecasts being accurate, ever, beyond more than a couple of weeks. Right now, we have a pretty good scale out to seven to ten days.

Mr. WU. Seven to ten days? Okay. Yeah. My Blackberry gives me six days, so it is within that margin.

Dr. ANTHES. Yeah.

Mr. WU. Yeah. Okay.

RESTORATION OF DROPPED NPOESS INSTRUMENTS

A more serious question. The Chairman referred earlier to the NPOESS program. And my understanding is that because of cost issues, cost overruns, that various instruments have been sort of thrown off the bus. And they tend to be the climate instruments. And Dr. Moore, you mentioned earlier that soil moisture is a very, very important factor to track for climate change purposes. And it also is the case that our military is very interested in soil moisture for other reasons. So I assume climatologists have a very strong interest in soil moisture for one set of reasons, and the U.S. armed forces have the same interest.

Now I think a list is coming of the various instruments, which were tossed off the NPOESS for budgetary reasons, and I just want—I am just asking you all, if you are familiar enough with it, if you could identify the order in which you would bring the cast-off instruments back. If you are not familiar with the hardware enough, at least the data streams that you would like to see, the cavalry coming, the data that you would like to see from NPOESS.

Dr. MOORE. Yes, Congressman Wu.

In the Decadal, we prioritize under a very limited basis. We recognized the budgetary difficulties. And the first was the Earth radiation budget instruments, that is to measure the solar radiance and the reflected energy off the planet. The second was the profile of ozone in the atmosphere, because we are in this period of regulation the fluorocarbons, and we are going to see, hopefully, the restoration ozone hole. Monitoring that profile, the different concentrations in altitude is the second priority.

Mr. WU. Would that be aerosols?

Dr. MOORE. No, that certainly is a priority, but now we are—we, essentially, felt that, given the constraints of the budget on NPOESS, that was about as far as we would recommend in terms of restoration.

Is that all we need to do? Absolutely not.

Mr. WU. I am sorry. I am just trying to look on my list here, and I am not finding an ozone meter, per se, but which instrument would that be in?

Dr. MOORE. Yeah. It is called ozone—the OMPS instrument. It is the limb-sounding aspect that was lost, the——

Mr. WU. OMPS limb.

Dr. MOORE. Right.

Mr. WU. Okay.

Dr. MOORE. That was lost, so that we are recommending to put back on, and the series and the solar radiance monitor we are recommending to put back on.

With regards to the soil moisture, that was to be measured by an instrument called CMIS. This is a follow-on to what is on the Defense meteorological satellites right now. Given the fact that that was the—descoped, we called for the preservation of sea surface temperatures and winds. And then we offset the loss of the soil moisture by recommending a NASA mission in soil moisture.

And I must say that there are a lot of very important measurements. For instance, sea surface altimetry that Dr. Anthes spoke about. The sea level height. That instrument is gone. We are trying to compensate for that by recommending an altimeter to NASA. It is true that most of the climate measurements were lost on NPOESS, and I think that perhaps the best strategy is the program we are recommending to NASA.

Mr. WU. If you are pushing over to NASA, is that realistic, given the budget crunch over on that side of the house, if you will?

Dr. MOORE. No, I——

Chairman GORDON. A quick answer, please, sir.

Dr. MOORE. I understand this budget issue and the budget crunch, but the fact remains is that the observational needs exist. And the budget was reduced over six years by a third. That seems to have been an error——

Chairman GORDON. The gentleman's time——

Dr. MOORE.—therefore, we need to restore that budget so that we can meet the observational needs of the planet.

Chairman GORDON. The gentleman's time has expired.

Mr. Rohrabacher is—has five minutes.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

First, I would like to congratulate you on your report and the hard work that went into this and the discipline necessary to actually come up with something that does not totally depend on what I consider to be a trendy issue of the day, which is climate change overall. You have made your arguments that included climate change as a reason, but you have well outlined your—you know, your—basically, the benefits that we will derive even if we don't have a global warming scenario. You have outlined the need for the type of observation that you are advocating.

And let me also note that it is unfortunate that we lost—I guess it was a $3 billion overrun for NPOESS. I mean, that is what we are talking about. The $3 billion, let me note, Mr. Chairman, what could we do with $3 billion? We could implement everything that is being said today. The request, basically, today is let us make up for the failure of NPOESS. That is basically what we are saying, because that is a six-year—well, they are asking for $500 million a year. It would put us back on schedule. And we lost $3 billion from just the overrun costs.

Let me add, there are some questions as to the reason why NPOESS failed. And some of the reasons—and I know people aren't going to want to hear this, but some of the reasons are additions to NPOESS, things that were added onto NPOESS that were designed to prove climate change, which helped the failure of NPOESS. So there is a cost when people go after things that maybe trying to stampede the public into spending more money for climate change that ends up a dramatic cost to other aspects of what we would like to achieve.

I was especially interested in the fact that this does measure sun and solar activities, which I believe are the basis for a lot of the—whether the human activity and carbon being put into the air, or hydrocarbons being put into the air and greenhouse gases may well explain why we have certain changes in climate and temperature on the Earth.

Let me ask this about, you know—we—again, you have given me a lot of information. And by the way, I would just say, again, I thank you for that, because I was listening intently, and I think you all made your point. And Governor, I am glad you were here to make a—to really tell us what it—how we—this is going to be cost-effective for humankind to know this, because it is. I mean, we are talking—you are not talking about contributing just knowledge. You are talking about contributing something that is going to change people's way of life for the better. And again, I think you have made your arguments today.

RECORD OF HURRICANE AND CYCLONE INTENSITY

The—I guess I don't—I was just taking notes while you were going through here. I—let me ask you, Dr. Anthes, is that how you pronounce it?

Dr. ANTHES. Anthes.

Mr. ROHRABACHER. Anthes. Are there more cyclones and hurricanes today than there used to be?

Dr. ANTHES. That is a very good question, and it is a hot topic of debate, I will put it that way.

Mr. ROHRABACHER. That is why I ask it.

Dr. ANTHES. We don't—I, actually, started out as a tropical cyclone research meteorologist. And I must say, because of the observational record being particularly bad before the advent of satellites in the 1970s, we have maybe 70 years, 80 years, 90 years of an incomplete—an imperfect satellite data record on tropical storms. So frankly, you know, you will read papers on both sides of this point.

Mr. ROHRABACHER. Okay.

Dr. ANTHES. Frankly, I don't know. I haven't made up my mind yet.

Mr. ROHRABACHER. All right.

Dr. ANTHES. And that is one reason for having these observations from space so that we know whether trends of intensity is increasing or not, because I don't think the evidence is conclusive yet.

Mr. ROHRABACHER. Now I will have to say, I sat through hurricanes when I was younger, when I lived in North Carolina, when I was in, like, sixth or seventh grade. And I read about the great hurricanes that came through Florida and Galveston, Texas. We know that they were very huge tropical storms then.

NEED OF SATELLITE SYSTEM FOR AGRICULTURAL PRODUCTION

One question for the Governor, and then I guess I—my time may be up.

Why is it—why do you see it being necessary to have a satellite system that gives an overall view of, for example, agricultural production? Don't we have enough computerization and records being kept throughout the states and by the Federal Government based on just the number of farmers and the type of bureaucratic efforts that we make? Don't we—isn't that accurate enough to see how many acres of corn we are growing?

Mr. GERINGER. Mr. Chairman, Congressman Rohrabacher, the—we do accumulate a lot of information, and one of the points I made is that we don't know how to discover and serve that information in a useful way. So that is part of the answer.

The other part of it is we don't know the extent. And I will give you a different example. It is not even in our country. There is a consortium of countries that have put together a satellite constellation called the Disaster Monitoring Constellation. That is the United Kingdom, Algeria, China, Nigeria—Algeria and Nigeria and Turkey. Now they launched these—constellation of low-cost satellites to monitor for disaster prediction and mitigation. But what they have done is they have started monitoring opium production in Afghanistan. Now they don't have quite the statistical reporting system that we have in the United States on opium production, but they have shown that in the 1 year from 2005 to 2006 that the opium cultivation grew by about 60 percent in Afghanistan. That affects us. It doesn't affect agriculture. It affects everybody.

Now how do we truth what is reported on the ground through statistical reporting services the soil condition, the erosion, you know, the loss of forests and things like that? How do we truth that up with what is reported on the ground of what the satellites look at? The MODIS satellite is one of the key satellites that we use for that kind of information, in addition to Landsat. So there is—it is the ability to know what you have, the quality of the data, how to use the data, and then how do you integrate it to where you can make an overall decision, a systematic decision, not just a knee-jerk type of one.

Mr. ROHRABACHER. Well, thank you very much. And again, I think you have made your case, and I appreciate good suggestions, by the way, as well, not just making the case for the expenditure but suggestions on how we can manage the system and do a better job for—and be more effective for what we do spend.

So thank you very much.

Chairman GORDON. The gentleman's time has expired.

And I will say that, Mr. Rohrabacher, your line of questioning always makes for a better hearing, and we thank you for it. But I will point out one thing, that the knobs on the global warming instruments go both ways. So it is not just to prove it. It could be also to disprove it.

The gentlelady from Texas, Ms. Johnson.

CONSEQUENCES OF GAPS IN DATA RECORDS

Ms. JOHNSON. Thank you very much.

And thanks to the witnesses for being here. It has been interesting. I guess I have a question that might be considered kind of dumb.

But when we have interruptions of observation where—no matter what causes it, is it thought that we miss something in the meantime, or does it interfere with how we work to certain points?

Dr. ANTHES. Well, that is—it is not a dumb question.

Explaining why gaps in the data record are important is not that easy, but let me try.

If you are looking at a—say, a 20-year cycle, and you miss seven years of that cycle, you are not going to be able to tell what that cycle really is if you are missing seven years out of 20. So that is one reason.

Another reason is a gap at the end of the record, in other words stopping a measurement, is the worst gap of all, because you don't know whether the last little up tick or the last little downturn is continuing for the—you know, into the future or not. If you look at any record, you will see this kind of thing. If you stop at this point, when you are going down and the gap starts, you don't know whether that turns around and starts coming up again or if it continues to go down.

So gaps are a very important problem in terms of understanding cycles and trends of whatever it is, sea level, temperature, water vapor, precipitation, drought frequency, whatever.

Ms. JOHNSON. So when you have great reductions in the budget and perhaps gaps, is it worth the investment to start and stop, start and stop, or—and do we get any real useful information, or are we wasting money if we don't do it any better?

Dr. MOORE. I think one of the challenges, and I believe the Governor noted this also, is the question of sustainability of the observation system. And that actually carries with it some real requirements.

Instruments don't last forever, and that is why we have gaps. One of the problems is that if you are measuring something like temperature, and it is increasing slowly, and that instrument fails and then we put another temperature instrument on orbit, if we don't overlap those two instruments, how are we then to interpret what the new instrument says? For instance, maybe the new instrument shows temperature increasing even more rapidly. Is that because it is a new instrument, or is that because of what the temperature is doing?

So the issue of sustainability is the—is right at the core of what we are addressing.

Ms. JOHNSON. Um-hum. Thank you.

PHYSICAL IMPROVEMENTS VS. ENVIRONMENTAL IMPROVEMENTS

There is no question in my mind about climate change. If you live and breathe every day, you can observe it.

What—where my questions still are is if we don't find much of the reason and start to correct that, where do we go from here? I went over and looked at the results of the tsunami. And as we returned, the latest rumor was that it might happen in California, and so that was an urgency to see if they couldn't get the observation network in place.

What comes next? I mean, we can observe, and we can predict, and I know that we have lost—we have saved a lot of lives by predicting, but we haven't done very well with property. I am fully aware that if we had worked on levies when we were supposed to back in New Orleans, it probably would not have been as bad. But predictably, would it have come? And—because, according to the simulations that we had observed, it was coming. And I don't know whether we concentrate on making sure that levies are strong or that we concentrate on changing something in the environment where we can avoid some of the destruction if we had an idea of what we needed to do.

Mr. GERINGER. Maybe I can answer it in a little different way.

I was visiting with the executive of King County, Washington about a week ago, and he is taking an approach that if something does happen, based on climate change and causes the sea level to rise, what could be causing that, it could be the greenhouse gases. So they are taking an approach from two different angles. One is to reduce the amount of carbon that they use in King County, which includes a significant part of Seattle, Renton you know, those—where some of those companies are that we hear about, reduce the amount of carbon and at the same time, based on the prediction of sea level rise by 2050, raise their levies to where there will be no flooding. And then with the carbon that they have offset, that becomes a revenue-raiser for King County. They can sell and trade carbon credits.

So they are doing two things. One is they are decreasing the total amount of greenhouse gas, anticipating that there is still going to be a rise in sea level, and over time, of course—and the idea is that it flattens out or at least declines. So they are taking an approach like that where they, from a practical point of view, raise a little revenue but improve the situation as well.

Chairman GORDON. Thank you, sir.

The gentlelady's time——

Ms. JOHNSON. Thank you.

Chairman GORDON.—has expired.

Mr. Bilbray is recognized for five minutes.

GLOBAL DIMMING

Mr. BILBRAY. Thank you, Mr. Chairman.

Gentlemen, I come from an air-regulatory background, the Air Resources Board in California. And because of sensing and monitoring, we totally changed our strategy on air emissions. We had grossly underestimated the evaporative emissions, and we couldn't figure out what—where all it was coming from until we figured out it wasn't coming out of the tailpipe.

I am—my interest here is what you are proposing is giving us the tools to be able to develop and execute good policy.

And Governor, I think you are pointing out that remote sensing gives us the ability to monitor where we may not have records. And a good example is that the third world. So many people say the third world is not a major factor here. It is because we don't have any air indexing in the third world. And remote sensing may be the only way for us to detect what is going on there.

The question I have, Dr. Moore, would be one of the new factors that have been thrown out is the concept of global dimming. And some people may agree with it or totally ignore it, but I think that we have got to remember that when Roger Revelle talked about global warming 20 years ago, some people wanted to ignore him, too. Does our—does the remote sensing that we are proposing here give us the ability to at least monitor, maybe, the effects of global dimming and how particulate—suspended particulates may be affecting or moderating the climate change at this time?

Dr. MOORE. Yes, it does, Congressman. It directly addresses the question.

And you are absolutely correct in noting that the question of global dimming is fundamental to climate change. It is also fundamental to public health.

The issue of particulates and aerosols work the climate system both ways, both as a warming and as a cooling.

One of the missions that we recommend, which is called ACE, directly focuses on this question of aerosols and their influence on the climate system.

Second, we are also recommending a geostationary air quality mission, which I think would address some of the question that major urban cities are going to have as to how much of the pollution is local and how much of it is transcontinental.

Mr. BILBRAY. Okay. And that is essential data. I appreciate you bringing that—you know, pointing that out, because one of the problems I have had with federal policies on a lot of these issues was like the—mandate. They thought it was good. Within 24 months, California knew that the federal mandate was an environmental negative, not a positive. And hopefully, I think it is essential, Mr. Chairman, that this issue will affect the total strategy. I think a lot of people are saying, "Just do something about global warming." Well, we could be doing exactly the wrong thing at the wrong time if we don't get the right facts.

And in fact, right now, in California, we are moving strategies ahead that assumes that the dirtiest technologies should be the first eliminated. But that may be the worst thing we do.

So hopefully, you will be able to give us the information so that we not only are well-intentioned, but we are smart in the way we apply this. And that is what scares me to death is this rush to do anything could end up creating more problems than an informed and appropriate approach to it. And that is essential on this. And I—and hopefully the data on global dimming can be settled before we settle on a strategy.

Dr. Anthes.

Dr. ANTHES. Anthes.

Mr. BILBRAY. Anthes. Dr. Anthes, let me just say, I appreciate you talking about the tropical storm issue, because, like my scientists at Scripp say, it is interesting that last year, global warming caused all of the big hurricanes, but this year, nobody talked about it. Well, it must be global cooling, because we didn't have any. And I appreciate the fact that you keep things on a balanced keel here, because it hurts the credibility of scientists when politicians start throwing around your data without having the facts.

But I have a question for you.

REMOTE SENSING AND EARTHQUAKE ACTIVITY

I come from the State of California. Hurricanes and tropical storms haven't historically been a problem for us because of the cold water. That may change in the future. But you brought up the issue of being able to detect tsunamis, earthquakes, and other related seismatic activity that normally isn't an—remote sensing isn't a big deal out—except maybe observation. How long do you propose to use remote sensing to predict earthquakes, which then result in tsunamis and all of the other activity you were talking about?

Dr. ANTHES. Okay. Well, that is a really good question, and I am not a geologist, so I will just have to—but the—one of our missions, which measures, very precisely, very small displacements in the surface of the Earth. If you do a time lapse of these—I have seen these. If you do a time lapse of these, you can see the Earth breathing. In fact, I can show you valleys in California, which are just——

Mr. BILBRAY. Much like the same way we measure El Niño by looking at the rise and fall of the ocean.

Dr. ANTHES. Of the sea surface height. Right. Well, the Earth is actually changing its elevation by centimeters over time. And if you see—well, first of all, by measuring these—where the Earth is changing its elevation and pulsating, these are active geological areas. These can help you, as I understand it, increase the probability of saying, "Well, an earthquake is going to occur here," or "A volcano is going to occur there," and of course, also then monitor tsunamis when they actually occur because of the change of ocean levels.

Chairman GORDON. Doctor, we are going to have a vote pretty soon, so if you don't mind, we are going to—I think we should move on here.

Mr. BILBRAY. No, no. I just don't know how you are going to measure pulsating in Los Angeles. It always pulsates. So that is just a given.

Thank you very much.

Chairman GORDON. Dr. McNerney is recognized for five minutes.

POTENTIAL FOR PRIVATE OR INTERNATIONAL PARTNERSHIPS IN REMOTE SENSING

Mr. MCNERNEY. Thank you, Mr. Chairman.

I want to thank the distinguished panel for their work in this area. I think it is a very important area.

I was intrigued by Dr. Anthes' comments that some of the work—some of the missions will be to identify the small difference between radiation to the Earth from the sun and then radiation from the Earth as a consequence of that. And I think that is a very important thing.

I noticed last week my distinguished colleague from southern—from Orange County asked some very pointed questions about wanting to know how—exactly how much of the carbon dioxide in the Earth's atmosphere was created by human activity. And I know that is a very complicated question, and the balance—or the issue between science and politics is a tricky issue. And it is our responsibility to have sort of a responsible pathway between those. And I think this is exactly one way that we can move forward to answering those kinds of very difficult and detailed questions.

So one of the things I want to know is is there any opportunity in private and international partnerships to help us move forward in this—in these kinds of missions.

Dr. Moore.

Dr. MOORE. I think that there is, and in our Chapter 3 where we talk about implementing the missions, the very first thing we explore is leveraging foreign partnerships. And if you are, for instance, looking at something like the measurement of carbon dioxide that you mentioned and where is it coming from and where is it going to, that is an ideal example of what we could do internationally. The—using a synthetic-aperture radar to get the slight differences in the elevation of the planet and how those might lead to earthquakes, that is another great example of where we could collaborate internationally. Our European colleagues have made great advances with synthetic-aperture radar. And so this would be another, because these are global issues. They are not just issues to one area of the planet. Earthquakes occur globally. CO_2 occurs globally.

Mr. MCNERNEY. How about the private partnership opportunities?

Dr. MOORE. I think the private partnership opportunities are extraordinary, particularly when you look at issues of land remote sensing, hyperspectral imaging. That looks at the reflected sunlight in many different wavelengths. This is a marvelous item for forecasting crop diseases. This is right on the border of what could be done commercially, and I think the Governor has really spoken out on this. This is a great opportunity.

Mr. GERINGER. One other comment I would make is if we don't keep up and we lose our edge in competitiveness, we lose two things. With international cooperation, such as through the Global Earth Observation System of Systems, we develop relationships so that we can understand and trust what we are getting back. Otherwise, we could be excluded, and the competition, then, leads the way. Who would we rely on to obtain the information we have no capacity to produce? So we need that kind of participatory opportunity as well as the leadership to make it happen.

Mr. MCNERNEY. Okay. I yield the balance of my time.

Chairman GORDON. Thank you.

And the gentleman from Michigan, Dr. Ehlers, is recognized for five minutes.

Mr. EHLERS. Thank you, Mr. Chairman.

First of all, Dr. Anthes, I am very pleased to hear your comment about the Earth rising and falling several centimeters a day, and now I know why I feel taller on some days than others.

I also presume that my weight varies, because I am further from the center of the Earth.

At any rate, more seriously, I can believe that a physicist just made this comment. I am very concerned about NPOESS, and we—you have talked about that in response to some other questions. I am very worried about the removal of some of the climate sensors. And clearly, we are not going to be—not going to have an optimized system. They are being removed simply because the cost of the project got too great, and we had to get somewhere.

You have talked a bit—Dr. Moore, in fact, just mentioned in the last question international work. What efforts are being made or what do—efforts do you think should be made to try to get more international cooperation in some of these satellites? I know other nations are putting up their own satellites, but in a case like this where the entire international community would benefit from the additional climate observations that NPOESS could make, do you believe our nation should aggressively pursue the possibility of getting assistance, cooperation, and money from other nations? And would we be likely to succeed in that effort?

I would appreciate any comments you have.

Dr. ANTHES. Well, I will take—a quick answer.

Absolutely, we should. We should try all of these avenues and approaches.

The United States, historically, has been the world leader in observations from space. In fact, the Europeans probably, I could argue, are making better use of the observations that we take than we are making—them ourselves, and this gets to the Governor's comments about it is more than just observations. It is how you use the observations.

International cooperation is a two-edged sword. It can save money and distribute resources more equitably and cooperation and sharing and all of that. But there are other issues that make these international programs hard to manage. If one partner has—runs into funding problems, it jeopardizes the mission. If a country, which is friendly now, turns unfriendly 10 years from now, you may not be able to get their data. There are ITAR issues about transferring technology to foreign countries.

So yes, I agree we should pursue it aggressively. Probably it is not a substitute for having our own, robust program. But we should try to leverage the international partners wherever we can.

Mr. EHLERS. Other comments?

Dr. MOORE. Just to note that that appears to be part of the plan to mitigate the NPOESS difficulties is to rely on the mid-morning orbit from the Europeans. But I also second what Rick Anthes just said, that it is a two-edged sword.

Mr. EHLERS. Now to what extent did your group, in doing the Decadal Survey, consider these issues? Did you come up with any particular recommendations on international cooperation and how we should proceed with it?

Dr. ANTHES. Well, we said, basically, what you just said. We should try every single opportunity that we can and try to reduce this overall cost by seeking international partners. And we didn't go any further than that. We didn't say mission number 13 should be an international one——

Mr. EHLERS. Right.

Dr. ANTHES.—but all of them should be considered. And if the international community comes up with one mission that reduces the need for us to do the same thing, we should consider lowering that in priority.

Mr. EHLERS. Do all nations freely share data with each other——

Dr. ANTHES. No.

Mr. EHLERS.—in these climate missions, or is it——

Dr. ANTHES. No.

Mr. EHLERS. Is it held very closely? Yes.

Mr. GERINGER. One comment I would make there, Congressman Ehlers, is if we don't have standardized protocols, data formats, and how we store and access information like that, it is not a matter of who is willing to share. It is a matter of whether you physically can or the technology isn't there to extract or transform to where you can use the data.

So the minimum we could do is establish standards and protocols, and that is where the Integrated Earth Observation System was intended to head with the international cooperations. Just having the data in the format where you can use it is a simple step.

Mr. EHLERS. And the other problem is getting all of the data down and analyzed quickly and properly. That is something I am also concerned about with NPOESS.

I yield back, Mr. Chairman.

Chairman GORDON. Thank you, Dr. Ehlers.

I think our final questioner will be our Vice Chair, Mr. Lipinski.

IMPACT ON AMERICAN COMPETITIVENESS

Mr. LIPINSKI. Thank you, Mr. Chairman. I know we are running short on time. I am going to make a quick question. I am not sure it is going to be a quick answer.

But, Dr. Anthes and Dr. Moore, in the report, it says, "At a time of unprecedented need, the Nation's Earth observation satellite programs, once the envy of the world, are in disarray."

I have a more general question. What impact does this have—do you see this having an impact on American competitiveness? Do you think it has a broader impact on our nation in that manner?

Dr. ANTHES. Well, that is a really good question.

The—one of the points we try to make in the Decadal Survey is that these observations are useful to society and useful in management of resources, whether it is energy resources, water resources, supporting agriculture. So it—there is an efficiency issue here that we can become, as a nation, more efficient if we have these better weather forecasts, seasonal outlooks, we know how to buy energy and store it for the cold spells coming up. And so I think you can make a very good case that these observations of the environment do affect, in a positive way, the U.S. economy, making us more efficient and so thereby improving our competitiveness.

My colleagues may want to add to that.

Dr. MOORE. I think there is another issue, also, that the declining budgets for Earth science at NASA send a signal to our graduate students and to our undergraduates as to what fields should they go into. And it is very tough to convince a young student that this is the direction that you want to take your life, because they say, "Well, there is no future in that."

So I think that there is a fundamental issue as to why students may not be going into Earth science or mathematics or physics, because they look at the trend. They are quantifying.

Mr. LIPINSKI. Having spent a few years in graduate school on my way to a Ph.D., finally, after many years, I understand the—you know, what impact that does have on what people are—what students are pursuing.

Thank you.

Chairman GORDON. Well, let me just say, this really was an excellent panel. And I thank you very much for this very informative meeting today. I want to particularly thank the Co-Chairs of the Decadal Survey for not just today but for two and a half years of hard, but important, work. This is a—really, a product that we need to have to try to move this decision-making process forward.

And Governor, you were a great breath of fresh air with the real-world approach, and let me please encourage you to continue to be active in these issues.

I understand that everyone who has wanted to have questions has done so.

Mr. Hall, once again, another good hearing. And if you have no more questions, then we will adjourn this hearing.

[Whereupon, at 11:40 a.m., the Committee was adjourned.]

Appendix:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Richard A. Anthes, President, University Corporation for Atmospheric Research (UCAR); Co-Chair, Committee on Earth Science and Applications from Space, National Research Council, The National Academies

Questions submitted by Representative Ralph M. Hall

Q1. NASA's experience with mission cost estimates is to be kind, not good. Many missions have seen their costs exceed even the most generous estimates. What level of confidence would you associate with the "rough" cost estimates ascribed to each of the recommended missions?

A1. The Committee stands by its estimates. The level of confidence associated with the cost estimates was given in Box 2–2 of the Decadal Survey report. The cost estimates are believed to vary from ± 50 percent for the smallest missions to ± 30 percent for the larger mission category. The survey report notes that, in general, cost estimates depend directly on the exact measurement requirements for the eventual missions. It also notes that the cost uncertainty rises for missions scheduled later in the next decade and for missions with the greatest technology development needs.

One historically large source of cost uncertainty is associated with technology development. When a mission's implementation depends on a technological advance, there's a risk that the mission will need to be delayed and that costs will increase if the advance doesn't proceed as expected. Effective mitigation of this cost risk involves early technology investment—and this is something that was strongly endorsed in our report. The committee suggests that NASA begin technology investments early to ensure the needed technologies are available before the mission implementation proceeds to the point where schedule delays incur large costs due to the large number of individuals entrained by the project (the so-called "standing army" problem).

Q1a. Do your cost estimates represent a full mission cost, to include the cost of building the satellite, launch services, operations, data analysis and research, and reserves?

A1a. The estimates include pre-launch costs associated with the instrument(s), the spacecraft and the launch vehicle, system engineering and spacecraft integration, science algorithm and ground data system development, and education and outreach. Post-launch costs included mission operations, data downlink, processing and archiving, science data development and validation. Post-launch activity duration was assumed to be three years for the NASA-recommended missions and five years for the NOAA-recommended missions.

These cost estimates do not represent a 'full' mission cost because they do not include the cost of the scientific analysis of the mission data. These costs were assigned to the mission-supporting part of the NASA and NOAA budgets.

Q2. You recommend that NASA increase its support for Research and Analysis to a level commensurate with ongoing and planned missions. What metric should NASA use to gauge R&A spending? Number of missions flying? Percentage of total program funding? How would you characterize the level of R&A funding currently provided in the Earth Sciences program?

A2. Historically NASA has invested approximately 50 percent of its funds for mission-supporting research. In the event that the NASA budget was restored to its year 2000 funding levels, the committee is recommending that the R&A and mission budgets be increased equally (i.e., maintain an approximate 50/50 split). This is our suggestion for the zero'th order metric for gauging R&A spending. If you want to consider metrics of the *impact* of R&A funding, some metrics for gauging this impact are the amount of satellite data available being used for analysis, the number of researchers supported, the number of peer-reviewed publications resulting from the missions, and the amount of satellite data being used effectively in weather forecast models and other applications.

Q3. In your testimony you state that the U.S. needs to continue to improve its climate models because those models are used in predicting El Niño and other seasonal weather patterns important to energy, water and agriculture management. Specifically which recommendations in the Decadal Survey relate to improving seasonal weather predictions?

A3. The following missions are identified as improving seasonal weather predictions, having direct impacts on energy, water, and/or agriculture management:

GPSRO (temperature and water vapor profiles), GRACE–II (changes in aquifers), HyspIRI (nutrients and water status of vegetation, soil health), PATH (temperature and water vapor profiles, sea surface temperature), LIST (global shifts in vegetation patterns, effects of land management), SCLP (water storage in snowpacks), SMAP (soil moisture effect on vegetation and freeze/thaw state), SWOT (lake, wetland, and reservoir storage), 3D–Winds (three dimensional tropospheric winds, improves El Niño forecasts), and XOVWM (surface winds over oceans).

Q4. In your testimony you say that due to declining budgets for Earth-observing satellites, air quality forecasts will become less accurate in the near future. Please elaborate on which satellites currently provide information important for air quality forecasts and why you believe this capability will be compromised in the near future.

A4. Air quality is determined by how much particulate matter (aerosols) and trace gases (ozone, NO_2 and volatile organics) are in the air. Air quality forecasting is a relatively new field that combines chemistry and aerosol models with weather models, which are used to move pollutants around. Aerosol measurements are being made by MODIS on Aqua and Terra, MISR on Terra, and OMI on Aura. Trace gas measurements are being made by Aura. The Aura measurements include ozone, NO_2 and hydrocarbons (formaldehyde). These measurements are being used in air quality forecast models on an experimental basis.

In the future, NPOESS will be making column ozone measurements with the OMPS instrument, however without the OMPS-limb sounding capability, we cannot estimate vertical profiles of tropospheric ozone. The OMPS limb instrument was deleted from the NPOESS payload in response to Nunn-McCurdy. OMPS will also not produce NO_2, hydrocarbons, or aerosols as Aura OMI does—the instrument is not capable of making those measurements. We will still get some aerosol information from VIIRS on NPOESS, but no information over clouds or bright surfaces (like deserts) because VIIRS lacks the near UV channels used by OMI for those kinds of aerosol measurements.

Q5. Acquiring, storing, and managing data comes at a significant cost. As we fly more sensors and gather more and precise measurements, how likely is it that the research community will argue that these capabilities must evolve into long-term data continuity missions? Of the seventeen recommended missions, how many of these would be one-time only missions that would not generate demand from the community for follow-on missions to maintain data continuity? Are NASA and NOAA at risk of being tasked with flying a greater number operational missions and gathering an increasing number of data sets?

A5. This is a great question, and one I cannot easily answer because the answer depends upon how useful the research observations are. Every research observation should be considered as a *candidate* for ultimately becoming part of an operational or sustained measurement system. The NRC has recommended in a previous report *(Satellite Observations of the Earth's Environment-Accelerating the Transition of Research to Operations,* NRC 2003) that an interagency transition office be set up that carefully evaluates the potential for every research observation to become operational. Cost-benefit considerations obviously will determine which observations are most valuable and should become operational. Not all research observations should be expected to become operational or sustained.

Questions submitted by Representative Ken Calvert

Decadal Survey Recommendations

Q1. How should NASA and NOAA interpret the recommended mission list? Your report suggests this list as a minimum set and notes the imperative that each mission be flown. But based on the experience of other decadal surveys, NASA has been able to fund only a fraction of recommended missions. Should NASA and NOAA prioritize the missions in the order listed? If so, which mission do you believe should be a priority?

A1. The Committee is acutely aware that evolving constraints have historically altered well-laid plans. To respond, we established a series of decision strategies and rules to be used for guiding any programmatic restructure. The study of Earth is a system science—the knowledge we seek derives from the mission set as a whole, not any single mission. The current list thus includes no prioritization other than a recommended ordering for launch, which itself is a prioritization. Changing the program is not as simple as dropping one mission from the bottom of a list and retaining the others; any single change implies the need to readjust the overall program. For this reason, our guidelines clearly state that such programmatic changes should be subject to advice from the broad community of Earth scientists and users.

At small budget deficiencies (e.g., ~10 percent), the proposed schedule can be stretched out. At larger deficiencies, the guidelines for adjustments to the missions come into play.

We emphasize again that the Committee believes the proposed mission set is indeed one the Nation both needs and can afford. It is a minimum mission set in the sense that its scope and budget meet an expectation of "reasonableness." Anything less than the proposed program falls short of what we believe this nation should reasonably pursue; it would place us at risk for maintaining scientific progress and achieving expected societal benefits. Additional budget enhancements should not be ruled out, and would support an even stronger program, with missions of great scientific merit and substantial societal benefit readily identified as new resources come available.

Q2. The Decadal Survey recommends restoring some climate sensors to NOAA's NPOESS program. This committee held three hearings on NPOESS in the 109th Congress and we learned that it's a troubled program, nearly $3 billion over-budget, and it faces tremendous technical challenges just to be able to meet the Nation's weather forecasting needs. Why should we add even more risk and potential cost to this program by restoring the climate sensors? What is the value to our citizens that would make the risk worth it?

A2. Important as weather sensors are, climate sensors are also important and cannot be neglected. Climate variability and change are among the most important environmental and societal factors affecting our future. So we have to meet the challenges of risk and cost of restoring key climate sensors. This may be accomplished in part by restoring a few climate sensors to NPOESS, AND launching some new missions as described in our report.

Climate monitoring requires a continuous series of high quality calibrated data. The solar irradiance sensor and the Earth radiation budget sensor are key to understanding climate change and are part of an unbroken series of measurements starting in the early 1980s. The Committee recommended restoring these climate sensors to NPOESS because under the current Nunn-McCurdy only the cost of the sensor was required—the IPO promised to pay for integration—this is the lowest cost approach. But if further deterioration of the NPOESS program occurs, it makes more sense to place these sensors on small spacecraft as has been done in the past (e.g., ACRIMSAT).

Venture Class Missions

*Q3. Your report recommends creation of a new competed mission line (*Venture *class) to replace the Earth System Science Pathfinder program, arguing that the latter has become a "competitive means for implementing NASA's strategic missions." Could you elaborate on this criticism?*

A3. The recommendation for a Venture class of missions is to encourage proposals for exploratory missions that are "out of the box"—ideas that the experts in NASA, on our committee, or in the broader community have not yet thought of. These should be creative, revolutionary ideas that could have transformative effects on science and applications. Venture class missions are NOT intended as a way to implement any of the 17 recommended missions.

Weather Prediction

Q4. NOAA was a co-sponsor of the Decadal Survey, yet your report has only three missions for NOAA compared to 15 for NASA. NOAA provides weather forecasts and warnings for the Nation—given its vital role, why did you have so few recommendations for NOAA?

A4. There were a number of factors that led to this result. Missions that were assigned to NOAA were those that were relatively low cost, ready to go operational, AND met a large number of the Panel's prioritization criteria. The fact that the NPOESS and GOES programs were (and still are) in a state of flux, with very uncertain budgets, was also a factor. Finally, the emphasis of the present plans for NPOESS and GOES is on weather forecasts and warnings, and so many of our recommendations addressed other important Earth science issues.

Q5. In your testimony you state that due to declining budgets for Earth-observing satellites, weather forecasts may start becoming less accurate. However, last year *this committee heard from the federal agencies responsible for weather forecasting (NOAA and the Air Force) that maintaining operational weather forecasting capabilities is their top priority and that future plans for weather satellites such as NPOESS and GOES–R will be just as good as, if not much better than, current weather satellites. Your claim contradicts these officials, so please elaborate on why you believe weather forecasts may start becoming less accurate.*

A5. Please let me be blunt here. Unfortunately, the recent track record of projections of the federal agencies responsible for space observing programs has not been reassuring, and even now the future of NPOESS and GOES, the observational foundations of our weather prediction capabilities from space, are uncertain. The steady increase of forecast and warning accuracies over the past 30 years has not been an accident—it has been the result of more and better observations and models. If the number of observations, which peaked in about 2006, continues to decline, at some point the trend of increasing forecast accuracy will reverse and the forecasts and warning accuracies will begin to decline. We do not know when or if this unfortunate point will be reached, but it is a risk as I stated unless we take action.

Q6. Please describe some examples of NASA research missions from the 1970's or 1980's that demonstrated capabilities now used for operational purposes.

A6. All of the current major operational satellite programs in NOAA can be traced to NASA missions. The current Polar orbiting operational satellites (POES) were derived from NASA's TIROS–N satellite launched in 1978. The NOAA GOES program can be traced back to the NASA Synchronous Meteorological Satellite launched in 1974. Finally, the Landsat series of environmental sensors can be traced back to the NASA Earth Resources Technology Satellite launched in 1972.

Q7. One key factor in the program design and cost of new missions is the availability of expendable launch vehicles. NASA acquires launch vehicles for science missions from commercial providers. How well is your recommended mission set matched to existing and planned commercial launch vehicle capabilities?

A7. Launch vehicle availability and cost have become moving targets. Launch vehicle costs, in particular, are very hard to pin down. The committee used the best available launch vehicle cost information (based on recently launched and known costs for currently planned missions). Specifically, the Decadal survey missions assumed the use of Pegasus, Taurus, or Delta II/IV launch vehicles. However, forward-looking launch vehicle cost estimates are subject to a large degree of uncertainty. Spiraling launch costs threaten the accuracy of any cost estimate until a contract is signed, and represent a large uncertainty in any cost estimate.

The futures of the launch vehicles assumed by the panel are uncertain, and this is a troublesome situation. If moderate capability launch vehicles are not available at a reasonable cost, an important element of programmatic robustness—our decision to recommend more, smaller missions rather than fewer many-instrument missions—becomes compromised. Should Delta-II class launch vehicles become unavailable, for example, the likely mitigation would be to pursue "co-manifested" launches, where multiple satellites share a larger launch vehicle. This is not as easy or straight forward as it might sound, as larger launch vehicles generally have larger vibrational loads during launch (meaning that the satellite structural design would have to be adapted), and would require ride-sharing missions to utilize similar orbits.

The committee is aware of private sector efforts to build low cost launch vehicles, which, if successful, will substantially mitigate these concerns. However, at present such launch vehicles have not been demonstrated successfully. The availability and cost of launch vehicles for scientific missions remains a serious concern of the committee.

Interagency Cooperation

Q8. What unique skills and expertise do you think NASA has in Earth-observing systems, and are the necessary processes for interagency cooperation in place to allow the country to benefit from those NASA capabilities? Can you please do the same for NOAA?

A8. In answering this question, I must necessarily generalize my response. NASA and NOAA, while having great records overall, do not have spotless records. Nevertheless, both agencies have many capabilities, skills, and expertise to be leveraged for Earth observation systems.

NASA has a long history of pioneering Earth research observation from space and in laying the groundwork for operational systems (see # 11, above). NASA expertise is primarily in technology, science, and engineering. NASA has demonstrated capability to manage technology infusions into missions, manage externally-developed technology contracts, and manage commercial suppliers and partner contracts with strong oversight. The more extensive competitive and peer-reviewed mission selection process at NASA has allowed for a more complete vetting of mission requirements, risks, and costs. NOAA has a strong history of operating ground systems for its operational programs, distributing data to a wide range of users, and producing decision-support tools and capabilities to directly serve well-specified needs. NOAA mission implementation typically is provided by a commercial contractor, with varying degrees of oversight.

In terms of knowing and understanding their user communities, NASA is tightly connected with the science and research community, while NOAA is more tightly connected with its operational end-users (meteorologists, the public, and decision-makers).

In order to use the strengths of both NASA and NOAA in a manner which maximizes benefit to society, interagency cooperation is essential. Currently, the necessary processes are not completely in place to optimize interagency cooperation. That is why the Decadal Survey recommends that the Office of Science and Technology Policy, in collaboration with the relevant agencies, and in consultation with the scientific community, should develop and implement a plan for achieving and sustaining global Earth observations. This plan should recognize the complexity of differing agency roles, responsibilities, and capabilities as well as the lessons from implementation of the Landsat, EOS, and NPOESS programs.

Among the key challenges confronting the two agencies are (1) the need for long-term, continuous, stable research focused observations of the Earth system that are distinct from the observations needed for operational weather prediction and (2) the need to systematically develop future operational systems in addition to the one for weather prediction. In order to address these challenges NASA and NOAA must improve their interaction early in the design process and overcome the natural disconnect that occurs because the two agencies have independent budget formulation processes and accounting systems.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Berrien Moore III, University Distinguished Professor, Director, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire; Co-Chair, Committee on Earth Science and Applications from Space, National Research Council, The National Academies

Question submitted by Chairman Bart Gordon

Q1. Please elaborate on the consequences of not executing the program recommended by the Decadal Survey, especially with respect to the societal applications of the observations and the importance of preserving particular time series, such as total solar irradiance.

A1. The consequence is simply that without the information, and then the scientific community will not have the basis for providing information to the country. It is hard to point to a specific consequence since there will continue to be some information on the planet from other sources. It is a bit like the question, what are the consequences if we did not conduct a census or monitor economic indicators. However, the question is certainly reasonable, and I shall address it by focusing on selected missions.

After CERES ceases on TRIMM and Total Solar Irradiance sensor on Glory, then we would cease to have the most basic climate forcing information, Given the fact that we "know" that the concentration of greenhouses gases will continue to increase in the atmosphere for at least the next 50 years, and that this change will force a change in the Earth energy balance, then we must monitor that energy balance and the solar output, if we are going to be able to make credible climate statements including forecasts. This is the reason, we recommend the CLARREO Mission.

Another example, the ASCENDS mission: We know without any question that the atmospheric concentration of CO_2 has risen by almost 40 percent since the middle of the last century, and that the cause of this rise is primarily fossil fuel combustion and secondarily land-use change. We also know that about 50 percent of the released CO_2 from fossil fuel combustion and land-use change is no longer in the atmosphere because it has been sequestered by the land biosphere and the oceans in approximately equal proportions. However, the proportional balance between land and oceans varies in time and space. The current state of the science cannot account for the growth rate and inter-annual variations of atmospheric CO_2 with confidence. The variability of the rate of increase in the concentration of CO_2 in the atmosphere cannot be explained by the variability in fossil fuel use; rather it appears to primarily reflect changes in terrestrial ecosystems that are connected with large-scale weather and climate modes. Finally and most importantly, we do not know the geographic distribution of the land and ocean sources and sinks of CO_2. This uncertainty is important. As nations seek to develop strategies to manage their carbon emissions and sequestration, the capacity to quantify the present-day *regional* carbon sources/sinks and to understand the underlying mechanisms are central to prediction of future levels of CO_2, and thereby, informed policy decisions, sequestration monitoring and carbon trading.

The current set of direct *in situ* atmospheric observations is far too sparse for this determination; moreover, the upcoming Orbiting Carbon Observatory, which will be a "Pathfinder" for ASCENDS, cannot make these measurements (because of limitations of sunlight) over many of the primary fossil fuel burning areas (Moscow, London, etc.) in the winter time nor is it able to make any nighttime measurements and hence OCO will not be able to determine regional sources and sinks of CO_2. ASCENDS will provide the measurements necessary to make this regional determination.

Similar statements can be made for every mission—specific information is needed (like sources and sinks for carbon dioxide) and specific missions are recommended to obtain this information. We believe and the Survey documents that each mission addresses important questions by society. Without the information, then we will be less equipped to address a specific societal issue. We also framed the entire program at a budget level for Earth observation that is comparable to the levels of the 1990s.

Questions submitted by Representative Ralph M. Hall

Q1. NASA's experience with mission cost estimates is, to be kind, not good. Many missions have seen their costs exceed even the most generous estimates. What level of confidence would you associate with the "rough" cost estimates ascribed to each of the recommended missions?

Do your cost estimates represent a full mission cost, to include the cost of building the satellite, launch services, operations, data analysis and research, and reserves?

A1. We asked experts at Goddard, JPL, and Langley to provide informal cost analysis, not by particular mission advocates, but by seasoned mission planners who evaluated the costs of all proposed missions in a consistent objective way. These cost estimates were then reviewed by members of the survey team, some of who have extensive industrial experience in spacecraft design. There were also external reviewers of the survey with mission management experience, and they did not find the cost estimates to be unreasonable. The mission's costs provided in Part II of the Report, *do not* include ground costs such as data analysis and longer-term mission management; however, these costs *are included* in the growth wedge that we recommend in the "Mission Supporting" portion of the budget in Chapter Two.

Most important, the Decadal Survey is informing NASA, NOAA, USGS; Congress, and the American public what measurements need to be made and what missions flown so that we can understand our planet and apply this understanding to societal benefits—benefits that will repay the Nation many times over. This answer *does not change* even if our cost estimates have small or modest systematic errors. Moreover, we recommend in Chapter Three of the Decadal Survey steps to take if costs grow beyond our estimates.

Q2. You recommend that NASA increase its support for Research and Analysis to a level commensurate with ongoing and planned missions. What metric should NASA use to gauge R&A spending? Number of missions flying? Percentage of total program funding? How would you characterize the level of R&A funding currently provided in the Earth Sciences program?

A2. I would recommend that we rest R and A, in real terms, to the level in 2000 budget. The accomplishments of the 1990s were extraordinary and, in fact, this is what we are exploiting today.

Q3. Acquiring, storing, and managing data comes at a significant cost. As we fly more sensors and gather more and precise measurements, how likely is it that the research community will argue that these capabilities must evolve into long-term data continuity missions?

A3. Most of them since the data needs are on-going. This is the simple fact of our situation on the planet. I do believe that costs can be driven down by better management and through technological advancements. We must avoid the NPOESS approach and the mismanagement.

Q3a. Of the seventeen recommended missions, how many of these would be one-time only missions that would not generate demand from the community for follow-on missions to maintain data continuity?Are NASA and NOAA at risk of being tasked with flying a greater number of operational missions and gathering an increasing number of data sets?

A3a. I believe that almost all will need to become "operational." We believe that the country needs to recognize this need and to consider new organizational structures for meeting this need in a reliable, cost-effective manner.

Q3b. Are NASA and NOAA at risk of being tasked with flying a greater number of operational missions and gathering an increasing number of data sets?

A3b. Yes, but we also believe that we can do a much than the performance of the recent past. We simply must recognize the challenge before us.

In sum, we are in need of knowledge of the Earth. We know that there is that the planet's environment is changing on all spatial scales including global, and change is rapid, likely more rapid than at any time in human history. Many of these changes are occurring because of human activity. These human-induced changes are over and above the stresses imposed by the natural variability of a dynamic planet.

The changes cascade through the Earth's environment in ways that are difficult to understand and often impossible to predict. At the least, these human-driven changes in the global environment will require that societies develop a multitude of creative responses including strategies for mitigation and adaptation. The linked challenges of confronting and coping with global environmental changes and addressing and securing a sustainable future is daunting and immediate, but they are not insurmountable. The challenges can be met, but only with a new and even more vigorous approach to observe and understanding our changing planet.

Questions submitted by Representative Ken Calvert

Decadal Survey Recommendations

Q1. How should NASA and NOAA interpret the recommended mission list? Your report suggests this list as a minimum set and notes the imperative that each mission be flown. But based on the experience of other decadal surveys, NASA has been able to fund only a fraction of recommended missions. Should NASA and NOAA prioritize the missions in the order listed? If so, which mission do believe should be a priority?

A1. We believe that the list represents the appropriate balance of missions in roughly the appropriate order (considering costs, technology issues, and science balance). We recognize that there could be a "number of missions" shock, and we could have "packaged" the missions on three larger platforms and reducing our recommended missions to three, which could have avoided this "number of missions" shock. This, however, would not have been wise since it would not produce a robust program. We also note that the missions listed in the last time-frame (2016–2020) would likely be revisited by the next "Decadal Survey," which is consistent with other Decadal Surveys. We believe that we have the right order, but again, as we note in our recommendations, the order could be varied slightly because of emerging science or policy priorities or because of technological readiness. We again stress the importance of embracing the Survey and beginning work on approximately half (seven to eight missions) of the missions at roughly $10M per mission per year to address key technological issues or costs concerns. Start these now with extended Phase A efforts—not simply "study" contract. Finally, we would like to again warn against growing any of the missions by increasing the requirements—this warning is made in the Survey, and we already hear reports that it is happening. *We must not let the perfect become the enemy of the good.*

Q2. The Decadal Survey recommends restoring some climate sensors to NOAA's NPOESS program. This committee held three hearings on NPOESS in the 109th Congress and we learned that it's a troubled program, nearly $3 billion over-budget, and it faces tremendous technical challenges just to be able to meet the Nation's weather forecasting needs. Why should we add even more risk and potential cost to this program by restoring the climate sensors? What is the value to our citizens that would make the risk worth it?

A2. We understand that the NPOESS program is a great disappointment. The possible causes for the programmatic difficulties are discussed in Chapter Three of our Report. We also recognize that the cost-benefit ratio of NPOESS compared with POES and DMSP is very troubling. NPOESS was sold as both a climate and weather program, and it seems appropriate to retain some climate capability. Moreover, we believe that our recommendations are not expensive and are, in fact, probably in the noise of the planned program and would not increase the program risk. This said, we share the Congress's disappointment and concern (see Response to Question #4 below) in the NPOESS program. Finally, the failure of the NPOESS program to meet the originally observational schedule and plan increases the importance of the recommended NASA missions.

Venture Class Missions

*Q3. Your report recommends creation of a new competed mission line (*Venture *class) to replace the Earth System Science Pathfinder program, arguing that the latter has become a "competitive means for implementing NASA's strategic missions." Could you elaborate on this criticism?*

A3. The criticism is four-fold. First, beyond the Glory, Landsat Continuity Mission, and the GPM, there is no planned program except for the Earth System Science Program. This makes no sense—a program must have planned priorities missions that address recognized needs. This we have tried to set forth in the Decadal Survey. The second problem is that it is very difficult to address the technology needs for a program that is primarily composed of unnamed missions, such as the Earth Science Pathfinders: How can one know in what technologies to invest? Thirdly, there are missions, which are needed that are more expensive than the ESSP missions, and yet nothing is provided for these medium to larger class missions. Finally, the promised timeliness (one or two missions every three years) for the ESSP program is a *broken promise.*

Weather Prediction

Q4. NOAA was a co-sponsor of the Decadal Survey, yet your report has only three missions for NOAA compared to 15 for NASA. NOAA provides weather forecasts and warnings for the Nation—given its vital role, why did you have so few recommendations for NOAA?

A4. We restricted greatly our recommendations to NOAA because of the damaging cost-growth of the NPOESS and GOES programs. We simply could not see the logic in asking NOAA to do much beyond the modest but high priority recommendations that were made to NOAA in the Decadal Survey (see again my Response to Question #2). We would also point out that Chapter Three contains additional NOAA-focused recommendations (e.g., production of Climate Data Records from NPOESS). The programmatic failure of NPOESS is very damaging.

Q5. Please describe some examples of NASA research missions from the 1970's or 1980's that demonstrated capabilities now used for operational purposes.

A5. For this early period, one would site primarily the Landsat plus the early NASA missions in both polar orbit and geostationary (e.g., cloud imaging) that set the stage for POES (and DMSP) and GOES. More recently, the ocean topography mission (TOPEX), the AIRS instrument (measuring humidity and temperature profiles) on EOS/Aqua, the TRIMM mission, and the sea surface winds from QucikScat are all being used operationally.

Launch Vehicles

Q6. One key factor in the program design and cost of new missions is the availability of expendable launch vehicles. NASA acquires launch vehicles for science missions from commercial providers. How well is your recommended mission set matched to existing and planned commercial launch vehicle capabilities?

A6. This is a very important question. There are many reasons (robustness, reduction in risk, smooth(er) budget ramps, flexibility) that support our recommendation to fly smaller, less complex payloads rather than the larger platforms such as NPOESS. The one drawback is the reduce launch capabilities (e.g., no more Delta-IIs) that may face the USA in the future coupled with the "skyrocketing" (pardon the pun) launch costs. This is a national problem that goes beyond the Decadal Survey, but it certainly has a negative impact on the mission recommendations of the Survey. This issue should be addressed.

Interagency Cooperation

Q7. What unique skills and expertise do you think NASA has in Earth-observing systems, and are the necessary processes for interagency cooperation in place to allow the country to benefit from those NASA capabilities? Can you please do the same for NOAA?

A7. Focusing on the word "unique" somewhat restricts my response. NASA has a unique technological capability in both breadth and depth, in both the development of technologies and the management of technologies. Part of the NPOESS problem is that this capability was not adequately exploited. There are indications that the NASA–NOAA interaction is moving back to a position whereby NASA can better assist NOAA in developing and applying advance space-based technologies, but for NPOESS it may be too little too late. NASA also has a solid scientific staff, but it is not unique. In fact, the university community collectively is far stronger.

For NOAA, the "unique" capability is the "operational" infrastructure to exploit space-based date for weather forecasting. This is of very high quality and a unique national asset. I think that the NASA–NOAA (and with the Air Force and Navy) interaction through the Joint Center for Satellite Data Assimilation forms a firm foundation that assist NOAA's capability (and the DOD's) to forecast the weather, but this could be improved and expanded upon-particularly in the area of climate research.

ANSWERS TO POST-HEARING QUESTIONS

Responses by James Geringer, Director of Policy and Public Sector Strategy, Environmental Systems Research Institute (ESRI)

Questions submitted by Representative Mark Udall

Q1. The Decadal Survey report discusses issues beyond the climate change issue, such as population increases near earthquake faults, shortages of clean and accessible fresh water, degradation of terrestrial and aquatic ecosystems, increased in soil erosion and declines in fisheries. Do the Recommended space missions help address such non-climate challenges and societal benefits? What other societal issues should be addressed?

A1. The Decadal Survey report highlights many other Earth science areas of practical, economic and societal benefit. The recommended space missions help address such non-climate challenges. However, NASA's budget priorities focus on just a few larger missions such as the Global Precipitation Mission (GPM) and Landsat Data Continuity Mission (LDCM) which seems to preclude other important environmental observations such as crustal stress and soil characterization.

The Decadal Survey does recommend missions that would monitor crustal movements and determine changes in strain and stress through the earthquake cycle. We should also enable better assessments of potential and actual damage from natural disasters and help target mitigation, recovery and relief activities.

Earth observation can dramatically benefit the competitiveness of our U.S. economy. Ocean observations are vital to transportation and trade. Improved weather forecasting enables more efficient energy use. Success of the emergence of carbon trading market will significantly depend upon our ability to monitor for compliance and improvements. Change detection that is possible only with remote sensing allows better and more timely policy decisions.

The NASA budget request does not appear to contain sufficient funds in the 2008–2012 timeframe to seriously begin any of these important missions. Instead, nearly all of the funds available for mission development are directed at just the two missions, the Global Precipitation Mission and the Landsat Data Continuity Mission, both follow-ons of previous missions. The LDCM is not widely supported as the type of satellite that would recognize trends in today's global setting. For instance, trends in world population growth would point to two very pressing needs: adequacy of food and water. Space missions should be tied to real world problems, not just arcane research goals.

Access to NASA data has been an issue. We need a more streamlined process to enable public access to remotely sensed data for the public, educational communities, agricultural producers and industries.

Compliance with industry standard file formats along with well-documented interpretation of these remotely sensed data products would enable utilization of data to support weather forecasting, disaster management, and commercialization.

Based upon anecdotal information, a number of people are not happy with the configuration and approach being taken for the LDCM. I have received letters from academics, scientists and policy-makers, including the Chair and Vice-Chair of the Western Governors Association who want specific water monitoring capability enabled with a thermal sensor which is not now included in LDCM planning. With what appears to be a growing disagreement on LDCM capabilities and cost, I recommend that a roundtable be convened by a neutral third party to examine the Landsat Data Continuity Mission approach. An organization such as the Institute for Global Environmental Strategies (IGES) could bring together the interested scientists and other parties to arrive at a community consensus.

Q2. What kind of Earth- and ocean-based systems are needed to complement the space missions?

A2. We need a system such as the Integrated Earth Observation System (IEOS), consisting of space, ground, airborne and ocean-based sensors, both public and private, that can gather information and integrate it for researchers and decision-makers alike with a maximum of efficiency and a minimum of duplication.

The President's FY 2008 budget recommends partial funding for the proposed Integrated Ocean Observing System (IOOS) to develop regional networks of remote ocean sensors, including biological sensors, that would monitor the general health of the ocean. Much more is needed so that we can better manage our coasts, improve hurricane and tsunami predictions, and improve marine operations. IOOS would include space, land, ocean and airborne sensors and application programs.

An excellent example of what IEOS and IOOS should be is the National Weather Service (NWS) within the National Oceanic and Atmospheric Administration (NOAA). The NWS provides the world benchmark for collecting and integrating weather observations from various sources across the globe to produce critical information that protects U.S. citizens and property. The forecasts that result from combining observations from space-based satellites, ocean buoys, ground-based systems and aircraft impact U.S. citizens daily in a wide variety of ways. The integrated information approach of the NWS should be scaled up to include other programs within and across several federal agencies.

Meaningful data gathering systems are possible at much less cost than space based platforms. Constellations of lower cost satellites have the potential to deliver more data more often at less cost than single, complicated, one-of-a-kind expensive satellites.

Ocean based systems of observation such as Royal Caribbean's "Explorer of the Seas" with its ocean and atmospheric sciences labs are an excellent example of low cost but very effective private partnership that should be encouraged and extended to other cruise ships and ocean going platforms. They provide an excellent means to verify on-the-water observations and collect long-term data sets at a fraction of the cost of other methods. One person who has been the visiting scientist three times aboard ship and has experienced it all first hand, describes it as a "very neat and a great way to improve ocean literacy!"

Q3. In your testimony, you identified leadership issues as impediments to effectiveness of the U.S. Earth Observations Program and to executing the vision and recommendations of the Decadal Survey. How should these issues be addressed?

A3. We must answer the simple question "Who's in charge?"

Current Earth observation systems are highly fragmented with different systems that were set at different times by different organizations and overseen by different Congresses for a variety of different reasons. Few are cross-correlated to complement each other's efforts. We do not have a coherent, integrated system to gather data, disseminate it through public portals for research and analysis, analytical tools to determine proper choices that can enable public policy-makers and private business leaders make better decisions. We risk becoming dependent upon other world countries to be the primary source of our data.

For example, the USDA is no longer using Landsat imagery for operational monitoring applications because of the data gap. Our current capability provides no global coverage for crop estimates and food production, no adequate revisit cycle for verification and trend analysis and it is not the best value for USDA. The solution for USDA/Foreign Agricultural Service is to contract with India to obtain imagery supplemented by information from commercial sources such as GeoEye.

We have recommended the convening of a high level commission that would have specific timelines and tasks to recommend action, legislation and funding that would be carried out by a cabinet level agency. Creation of an IEOS program office would enable us to forecast events in our oceans and on land even before we see changes in the atmosphere. Connecting disparate observations into national systems would enable us to anticipate and even prevent key environmental problems or at least detect them earlier to mitigate the effects. We should leverage the time and resources already invested in systems development, data collection and analysis, and modeling to create a comprehensive and actionable vision of our world.

I support the Decadal Survey recommendation for establishment of an office of coordination within OSTP. But we need more than coordination. We need leadership enabled with authority and motivated by passion, not just another block on the organizational chart. As part of a national strategy, we should address how to more effectively move from research to operations. Our global competitiveness depends on how quickly and effectively we act.

Questions submitted by Representative Ken Calvert

Q1. In the agricultural industry, to what degree is remote sensing data conveniently available to individual farmers to help them plan and manage their crops?

A1. A moderate amount of remote sensing data are conveniently available, however, the raw data are of limited use unless they are incorporated into a decision support tool that merges the data with other information in the context of a farmer's needs. Also, the remote sensing data must be timely and of a sufficient scale to make them useful in an agricultural setting.

A wide range of remote sensing data from government sources is available to farmers. This includes information on weather and climate, imagery of fields and roads (base data layers), elevation, and hydrology. The private sector is another important source of data. Private companies tend to specialize in custom data that are more current and of higher resolution. For example, a farmer may request that high resolution aerial imagery be taken of farmland at a specific time in the growing season. Meteorological data from the National Weather Service and private sector sources is accessed by farmers on a regular basis.

The U.S. Department of Agriculture sponsors the National Agriculture Imagery Program (NAIP), which acquires imagery during the growing seasons in the continental United States. Other federal agencies and a number of private sector companies develop a range of remote sensing data that is used for agricultural purposes.

Q2. Can they get the data off the Internet?

A2. Yes, but with a very significant caveat; namely, Internet access and speed.

Remote sensing data are available by way of the Internet from public and private sources both within and outside the United States. Remote sensing data from government sources are typically available at no or low cost. Private sector data are normally available for a fee.

The primary sources of information from the Federal Government are the U.S. Department of Agriculture (USDA), National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS). The National Aeronautics and Space Administration (NASA) is often a partner contributing to the development of these data through the development, launch, and operation of satellite systems. Some state agencies also make remote sensing data available.

Examples of government data used for agricultural purposes are:

USDA

- Digital quadrangles and mosaics via the National Agriculture Imagery Program (NAIP).

NOAA

- Weather and forecast information from the National Weather Service

USGS

- LandSat Imagery (base maps)
- Orthoimagery (Digital Ortho Photos, base maps)
- Elevation (Digital Elevation Models)
- Hydrography
- Land Cover (MODIS)

Examples of Internet-based information resources from the private sector or foreign governments are:

- High resolution aircraft-based imagery from numerous private sector sources
- High resolution satellite-based imagery from DigitalGlobe (U.S.)
- High resolution satellite-based land imagery from SPOT (France)

Information is of little value if agricultural producers don't have access or sufficient bandwidth. The National Agricultural Statistics Service most recent survey shows that 51 percent of U.S. farms have Internet access. The percentage increases to 72 percent at the highest level ($250,000+ income) but the number of producers at that level is small. Most producers who have Internet access use a dial-up modem which limits information and usage. The Pew Internet and American Life Project found that agricultural producers and rural communities do not have the broadband access that has become a basic necessity for economic development, small business growth, and education.

People in urban areas are twice as likely to have broadband access as their rural counterparts.

Actions by Congress should promote open access, meaningful competition, and innovation at the federal and State level for high-capacity rural broadband Internet access through public and private investment partnerships.

Q3. Is it routinely provided by the government through a private sector source?

A3. At present, the process of accessing data is cumbersome and time consuming. If farmers are to make more routine use of government data, the process for identifying and accessing it must be streamlined. There are great benefits to farmers in making use of remote sensing data for farm management and precision agriculture.

A direct benefit would be more efficient use of fertilizers and pesticides. It is important for federal agencies to make use of state-of-the-art data storage and delivery mechanisms to make data readily available to farmers and to private sector firms who provide information services to the agricultural sector.

Few farmers have the capacity to directly download and analyze remote sensing data. To be useful, a decision support tool is required to format the data, integrate it with other information, and display it in a useful format. A private sector company that specializes in providing this service for the agricultural industry is ZedX Inc. *(www.zedxinc.com).* Their decision support system called "AgFleet" is used to manage more than 15 million acres of agricultural land in North America. The tool makes use of remote sensing and other data from government and private sector sources to guide decisions about planting, harvesting, and application of fertilizers, pesticides and other chemicals. Crop consultants and dealers of seed, fertilizer, pesticides, and other agricultural chemicals typically provide this analytical service to farmers. The service allows them to determine what products should be applied when, where, and at what concentrations, and to track the financial costs and benefits of their farm management practices.

Q4. Can you offer an estimate of the percentage of farmers that access this type of data on a periodic basis?

A4. At present, a relatively small percentage of farmers nationally make use of advanced precision agricultural techniques which require access to remote sensing data on a periodic basis. This applies primarily to grain crops. A larger percentage of farmers make some use of remote sensing imagery as base data layers for farm management purposes. Again, few farmers make direct use of remote sensing data on a regular basis. Most often, crop consultants, major suppliers of seed and chemicals, and agricultural extension services develop information products for farmers that often incorporate remote sensing data.

Timeliness, availability, and cost of information are the major determining factors in the use of remote sensing data in agriculture. If timely, high quality data were available to farmers at low or no cost from either government or private sources, the number of farmers making use of precision agriculture practices would increase greatly. This would increase the profitability of farm operations by increasing crop yields and reducing expenses associated with agricultural chemicals. It would also decrease residues on agricultural products, and would minimize the runoff of chemicals into waterways.

As Congress considers the new farm bill, it should consider ways to encourage federal agencies to make high quality remote sensing data more readily available to farmers, and it should provide incentives for farmers to make use of precision agriculture techniques and decision support tools.

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