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NASA'S SCIENCE MISSION DIRECTORATE: IMPACTS OF THE FISCAL YEAR 2007 BUDGET PROPOSAL

HEARING

BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED NINTH CONGRESS

SECOND SESSION

MARCH 2, 2006

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NASA'S SCIENCE MISSION DIRECTORATE: IMPACTS OF THE FISCAL YEAR 2007 BUDGET PROPOSAL

THURSDAY, MARCH 2, 2006

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

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

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

Hearing on

NASA's Science Mission Directorate: Impacts of the Fiscal Year 2007 Budget Proposal

March 2, 2006
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

Dr. Mary Cleave
Associate Administrator
Science Mission Directorate
National Aeronautics and Space Administration

Dr. Fran Bagenal
Member
National Academy of Sciences Decadal Survey for Sun-Earth Connections
"The Sun to the Earth and Beyond" (2003)
Professor
Astrophysical and Planetary Sciences
Laboratory for Atmospheric and Space Physics
University of Colorado

Dr. Wesley Huntress, Jr.
Member
National Academy of Sciences Decadal Survey for Solar System Exploration
"New Frontiers in the Solar System" (2003)
Director
Geophysical Laboratory
Carnegie Institution of Washington

Dr. Berrien Moore III
Co-Chairman
National Academy of Sciences Decadal Survey for Earth Sciences
"Earth Observations from Space: A Community Assessment and Strategy for the Future" (expected fall 2006)
Director
University Distinguished Professor
Institute for the Study of Earth, Oceans, and Space
University of New Hampshire

Dr. Joseph H. Taylor, Jr. NL.
Co-Chairman
National Academy of Sciences Decadal Survey for Astrophysics
"Astronomy and Astrophysics in the New Millennium" (2001)
James S. McDonnell Distinguished University Professor of Physics
Princeton University

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HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

NASA's Science Mission Directorate: Impacts of the Fiscal Year 2007 Budget Proposal

THURSDAY, MARCH 2, 2006
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Thursday, March 2, at 10 a.m., the House Committee on Science will hold a hearing to review the proposed fiscal year 2007 (FY07) budget for the Science Mission Directorate of the National Aeronautics and Space Administration's (NASA), and to examine how that budget would affect research in space science and Earth science.

The proposed budget for science is a controversial aspect of NASA's FY07 budget request because it would result in the cancellation or delay of a number of missions and provides little funding for the initiation of any missions beyond those already in the queue for development or launch.

Witnesses

Dr. Mary Cleave is the Associate Administrator at NASA for the Science Mission Directorate.

Dr. Fran Bagenal is a member of the National Academy of Sciences Decadal Survey for Sun-Earth Connections, "The Sun to the Earth and Beyond" (2003). Dr. Bagenal is a Professor of Astrophysical and Planetary Sciences at the University of Colorado at Boulder.

Dr. Wes Huntress is a member of the National Academy of Sciences Decadal Survey for Solar System Exploration, "New Frontiers in the Solar System" (2003). Dr. Huntress is the Director of the Geophysical Laboratory at the Carnegie Institution of Washington and was Associate Administrator for Space Science at NASA from 1992 to 1998.

Dr. Berrien Moore is the Co-Chairman of the National Academy of Sciences Decadal Survey for Earth Sciences, "Earth Observations from Space: A Community Assessment and Strategy for the Future" (expected fall 2006). Dr. Moore is the Director for the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire.

Dr. Joseph H. Taylor, Jr. is the Co-Chairman of the National Academy of Sciences Decadal Survey for Astrophysics, "Astronomy and Astrophysics in the New Millennium" (2001). Dr. Taylor is a Nobel Laureate and Distinguished Professor of Physics at Princeton University.

Overarching Questions

The Committee plans to explore the following overarching questions at the hearing:

1. How did NASA determine its science priorities for the FY07 budget? To what extent are NASA's priorities based on the decadal surveys in which scientists determine the priorities for their fields? Do those surveys need to be redone now that science funding may be lower than was expected?
2. What impact would the proposed science budget have on the research agenda of space and Earth scientists? What technological advances and scientific discoveries may be delayed or foregone and how significant a loss would that be?
3. To what extent would the proposed FY07 budget make it difficult to attract or retain students or researchers in the space and Earth sciences? What

steps can be taken to ensure that these fields remain healthy in an era of budgetary constraints?

4. Has NASA provided an appropriate amount of money for science in its FY07 budget request, given the competing needs of science, aeronautics, the Space Shuttle and International Space Stations programs and the *Vision for Space Exploration*?

Brief Overview

The Budget

Under the Administration's proposal, spending for NASA's Science Mission Directorate would increase by 1.5 percent in FY07, to about $5.3 billion, which is about one-third of the total requested spending for all of NASA. The proposal projects one percent annual increases for the Science Mission Directorate in FY08–FY11. (Inflation is projected to increase at about 3.3 percent in FY07.)

This is a significant turnabout from what was projected a year ago. In its FY06 budget request, the Administration projected that spending on the Science Mission Directorate would increase by about seven percent in FY07 and that the Directorate would experience further strong growth in the four ensuing years.

All told, the FY07 budget request provides $3.1 billion less for the Science Mission Directorate for FY06 through FY10 than what had been projected as part of the FY06 budget request. NASA Administrator Michael Griffin testified on Feb. 16 that the money that was to have been spent on science would be used instead to fund the Space Shuttle program, which had been underfunded in the FY06 budget request projections. (Portions of the Exploration account were also reduced from earlier projected levels to cover Shuttle costs.) The cuts from the levels projected in FY06 will necessitate the cancellation or delay of missions and will make it difficult to initiate the formulation of any new missions. (Each mission spans many years from development through launch and operation.)

The Science Mission Directorate has also had to reassess its research agenda because of cost growth in several of it missions. The reason for this growth varies by mission: in some cases, original estimates were too optimistic about how difficult it would be to develop the technology; in other cases, policy changes have resulted in a change in the purpose or nature of the mission. (The specific cases are discussed below.)

The Programs

The Science Mission Directorate supports research in four major areas, each of which would see its program scaled back in the FY07 budget. Research in **Solar System Exploration or Planetary Sciences** seeks to understand the nature of the other planets in our solar system as well as moons, asteroids, comets through launching orbiters, rovers and other landers, and fly-by missions. Research in **Astrophysics** seeks to understand the origins of the universe, the physical laws of the universe, the nature of matter and energy and other aspects of astronomy through orbiting space telescopes and other space-based instruments. Research in **Heliophysics** or **Sun-Earth Connections** seeks to understand the impacts of the Sun on the solar system (including such phenomena as the solar wind and solar flares) through spacecraft-based sensors. Research in **Earth Science** seeks to understand the Earth's land, atmosphere and oceans and the interactions among them through satellites that orbit the Earth.

In each of these areas, the Directorate funds three types of activities, all of which would be scaled back. First, it funds major, flagship missions that require the cooperation of many scientists from NASA centers, universities and other research institutions to design, develop and operate. These missions are selected by NASA based on recommendations in scientific decadal surveys (see below). Second, it funds smaller, briefer, lower-cost missions that are selected through competitive peer review and that involve fewer institutions. Third, the Directorate funds research grants to scientists to study the data obtained by the missions through its Research and Analysis (R&A) programs. R&A funding is generally awarded through competitions.

The Scientific Community

Unlike what happens in most fields of science, scientists in the fields supported by NASA get together every decade to agree on the priority missions necessary to keep their fields moving forward. These "decadal surveys" are conducted under the auspices of the National Academy of Sciences (NAS) using funds from NASA. The non-NASA witnesses at the hearing participated in, or led (or are leading) the most recent decadal surveys in their fields.

The most recent surveys were completed for Sun-Earth Connections (projects currently within the "Earth-Sun System" division) in 2003, Solar System Exploration in 2003, and Astrophysics (the "Universe" division) in 2001. The Survey for Earth Sciences is currently being conducted. The interim report was released in April 2005 (and discussed at a Science Committee hearing shortly thereafter), and the final report is due in late 2006.

The decadal surveys are not based on any particular budget assumptions. The surveys do sometimes prioritize missions in different cost tiers rather than simply providing a single list of priorities.

Federal Agencies

Other federal agencies fund research in the fields supported by NASA. The National Science Foundation (NSF) funds ground-based telescopes that are also used for astronomy and astrophysics. NASA and NSF appoint a joint advisory committee on astronomy and astrophysics as required by the *National Science Foundation Act of 2002.* The National Oceanic and Atmospheric Administration (NOAA) also supports Earth satellite missions. Generally, NOAA's missions are for ongoing operational purposes, in contrast to NASA's time-limited research missions. NASA often develops new technology for its missions that is later put to use by NOAA after it has proved successful. The *NASA Authorization Act of 2005* requires greater coordination and joint reporting by NASA and NOAA. The Department of Energy (DOE) Office of Science funds basic research at colliders and other facilities on the nature of matter that is relevant to some of the questions NASA explores in astrophysics. NASA and DOE are working together on a Joint Dark Energy Mission.

Programmatic Details

Across the Directorate

Several reductions from previous plans are common to all the programs in the Science Mission Directorate. The cuts that are proposed across the Directorate have drawn the loudest criticism from the scientific community because they would have a widespread impact on researchers and students.

Funding for the smaller, lower-cost, competitively selected missions are cut throughout the Directorate. These missions, with their shorter development time, have been particularly important in training graduate students and other future scientists, as well as for rapidly addressing specific emerging scientific questions. The smaller mission programs include Explorer in the Solar System Exploration and Earth-Sun System divisions; Discovery in the Solar System Exploration division; and the Earth System Science Pathfinder (ESSP) program. Missions in these programs would be selected less frequently under the proposed FY07 budget. In the past, new missions were generally selected every two to three years. The FY07 budget would lengthen the gap between missions. For example, in the Earth Science program, the last new Pathfinder mission was selected in 2002, and, under the proposed budget, the next one is projected to be chosen no earlier than FY08.

In addition, funding for R&A was cut by 15 to 20 percent in each of the Directorate's fields on top of a reduction in FY06. The R&A account provides funds to scientists to perform research on the data collected by the various missions. NASA argues that less money is needed for R&A because fewer new missions will be launched. But there is a backlog of existing data, and R&A is the primary source of ongoing funding for academic scientists and their students in the fields supported by NASA. (Mission funding is largely eaten up by the cost of building and operating the instruments being flown.)

Solar System Exploration

Solar System Exploration is increased slightly (to $1.61 billion) compared to FY06 after sustaining significant cuts in FY06. That cut in FY06 resulted from the cancellation of several robotic missions to Mars that were intended more as precursors to a human mission than as scientific expeditions. In addition, Solar System Exploration would absorb the majority of the reductions from the projected spending that had been included in the FY06 budget proposal. From FY06 through FY10, the proposed FY07 budget provides $2.99 billion less than would have been spent under the FY06 projections. That cut also is largely due to the elimination of the Mars missions, which would have required continued spending over the period. NASA points out that even with these cuts, a new mission to Mars will be launched every 26 months. NASA also continues to operate several ongoing Mars missions, including the twin Mars rovers Spirit and Opportunity.

The scientific community has not raised loud objections to the revamped Mars program as most of the missions that were canceled were not primarily designed for scientific purposes. The canceled missions include the Mars Telecommunications

Orbiter, two Mars testbed missions, and future Mars human precursor missions. The Mars Sample Return mission to robotically bring back soil samples from the Martian surface is indefinitely deferred in the FY07 budget proposal.

Another impact of the reduced spending on Solar System Exploration is that the program will not be launching a new, large, flagship mission for at least 10 years. (The recently launched mission to Pluto, New Horizons, does not qualify because it is a less elaborate mission that will just fly by Pluto and was developed differently.) No flagship mission could launch for at least a decade because there is no such mission in development and no funds are provided in the FY07 budget runout to begin development on one. Previous flagship missions have included the Cassini mission to Saturn, the Galileo mission to Jupiter, and the Viking mission to Mars.

The highest-ranked mission in the most recent decadal survey for Solar System Exploration is a mission to Europa, a moon of Jupiter that may have, or may have had in the past, liquid water. NASA has started work on a Europa mission in the past, but then has pulled back for various reasons. (The most recent effort was canceled a couple of years ago when a program to create a nuclear propulsion system for the mission was stopped.) There is no money in the proposed FY07–FY11 budget for a mission, although Congress directed NASA in the FY06 *Science, State, Justice Commerce Appropriations Act* (P.L. 109–108) to begin planning a mission to Europa and include it as part of its FY07 budget. NASA points out that a mission to Saturn's moon, Titan, that sent back data after the decadal survey may indicate that Titan would be a better target for a mission than Europa.

Also under Solar System Exploration, the FY07 budget proposal cuts the Astrobiology program by 50 percent. NASA argues that the field is less pressing because no human mission to Mars is imminent. But it is not clear why such a mission would be the sole or even the primary reason to study the origins, evolution, distribution, and future of life in the universe, or the search for potentially inhabited planets beyond our Solar System.

Solar System Exploration also received the largest reduction to R&A of all the NASA Science divisions because of the significant cut in its overall missions rate and budget.

Astrophysics (which NASA sometimes calls "Universe")

Under the proposed FY07 budget, Astrophysics would see a small increase of about $2 million to $1.51 billion and then would begin to decline in FY08, ending in FY11 at about $1.31 billion. The total proposed over FY06–FY10 is about $380 million less than what had been projected in the FY06 budget proposal.

Astrophysics also would defer and may cancel several missions under the FY07 proposal. But in addition to the overall budget, Astrophysics needs to contend with significant cost overruns in a number of its missions, including its top priority, the James Webb Space Telescope (JWST), the follow-on to the Hubble Space Telescope. The FY07 budget also includes money for the servicing mission to the Hubble (excluding the cost of the Shuttle launch itself), which had not been included in the FY06 budget plan. Overall, funding has been provided for the large, long-term priorities like Webb and Hubble, while projects that were to begin development in the next several years, such as the search for extra-solar planets and the study of "dark energy," have been deferred.

NASA is planning a Shuttle mission to service the Hubble in 2008, assuming the next Shuttle flight shows the vehicle can operate safely. Over the last several years, NASA has implemented conservation measures to help extend the life of the batteries and gyros on Hubble so that it should remain operational into 2008. To pay for continued operations and preparations for the planned servicing mission, the FY07 budget increases funding for Hubble.

The FY07 proposal increases funding for JWST to cope with the projected $1 billion cost growth, and pushes back the launch two years to 2013. JWST is ranked as the top priority in the astronomy and astrophysics decadal survey. NASA is reviewing the program now, and expects to have a better handle on JWST cost estimates this spring, which will be reflected in the FY08 budget. Under its standard review processes, NASA will not make a final decision on launching JWST until next January.

The Stratospheric Observatory for Infrared Astronomy (SOFIA) program is zeroed out in the FY07 budget, but is under review. The SOFIA observatory, a heavily modified Boeing 747 carrying an infrared telescope, is a joint program with the German Aerospace Center. The project is significantly over budget and behind schedule. SOFIA was planned to work in conjunction with the Spitzer telescope, currently in operation, but now would have little overlap with Spitzer. SOFIA is still funded in FY06, but NASA has directed that no new work be started until the review is completed. A final decision on SOFIA is expected in the next few months. If NASA de-

cides to allow the program to proceed, it will look for cuts in other programs to find the funding.

The Navigator program, a series of ground-based and space-based telescopes used to detect planets around other stars, is cut significantly in the FY07 proposal. The programs under Navigator are the Space Interferometry Mission (SIM), the Terrestrial Planet Finder (TPF), the Keck Interferometer, and the Large Binocular Telescope Interferometer (LBTI). SIM is under review with a launch date of no earlier than 2015, pushed back from earlier projections of 2009 or 2011. TPF, which has had technical problems, has been deferred indefinitely. The Keck Interferometer is in operation, but proposed upgrades to improve performance are canceled.

The Beyond Einstein program fares poorly in the FY07 proposal. The program would receive 66 percent less over the FY06–FY10 period than had been projected in FY06. Beyond Einstein is designed to observe phenomena predicted by theoretical physics, such as phenomena that would shed light on the Big Bang, black holes, and the existence of a "dark energy." NASA plans to proceed with studies related to the missions in FY07. Missions being studied the Joint Dark Energy Mission, which would be run in conjunction with the Department of Energy.

Earth-Sun Systems

In the FY07 budget Earth-Sun Systems is treated as a single unit, although NASA is running the programs now through two separate divisions, Heliophysics (Sun-Earth Connections) and Earth Science.

The FY07 budget for Earth-Sun Systems provides about $302 million more than had been included in the FY06 budget for the division in FY06–FY10. The total proposed funding of about $2.2 billion in FY07 would be an increase of about $50 million over FY06.

But the proposed budget has still raised scientific concerns both because the FY06 baseline was a significant drop from previous years—the interim decadal survey called it "alarming"—and because the budget must accommodate increased costs for two projects related to problems with a satellite program run by the National Oceanic and Atmospheric Administration (NOAA).

Under the proposed FY07 budget, the flagship Earth Science mission will be delayed for budgetary reasons and virtually no funding is provided for any mission not already in development.

Most of the proposed increased funding will be directed instead toward two missions connected to the problem-plagued weather satellite program, the National Polar-orbiting Operational Environmental Satellite System (NPOESS). (NPOESS, which is run jointly by NOAA, the Air Force and NASA, is currently under review because it is more than 25 percent over budget and several years behind schedule. The Science Committee held a hearing on the program last fall.) The two missions are the NPOESS Preparatory Project (NPP), a precursor to NPOESS, and the Landsat Data Continuity Mission (LDCM). NPP has been delayed significantly because of technical problems with sensor development overseen by NOAA and the Air Force, thus increasing the total cost of the program. Landsat was originally to have flown as part of NPOESS—a White House decision—but now technical problems with that arrangement and the overall problems with NPOESS have led the White House to change course and have Landsat fly as a separate mission. Landsat satellites have been circling the Earth for decades providing large-scale imagery.

The flagship Earth Science mission is the Global Precipitation Measurement (GPM) mission, a joint U.S.-Japanese project intended to improve climate and weather prediction through more accurate and more frequent precipitation measurements. It was originally scheduled for launch in 2008. In the FY07 budget plan, the launch of GPM has been delayed to 2012. In its interim report, the Earth Sciences decadal survey recommended that the GPM mission "be launched without further delays." There is a growing concern among scientists that further delays in this program could have serious consequences for the international partnership, such as the loss of Japanese support for the program.

Questions for the Witnesses

The witnesses were asked to address the following questions in their testimony:

Questions for Dr. Mary Cleave

Please briefly explain the President's FY07 budget request for NASA's Science Mission Directorate and answer the following questions:

- How did NASA decide what missions to defer or cancel in response to the reduced spending growth for the Science Mission Directorate? Was funding first allocated among the different divisions or did you begin by evaluating mis-

sions across the entire directorate? To what extent did you consult with the scientific community in determining how to distribute the available funds?

- What is NASA doing to ensure that the U.S. will continue to have a robust scientific enterprise in the fields supported by your directorate and will be able to continue to attract new students and researchers? To what extent will this be affected by the proposed cutbacks in Research and Analysis and how was the size of those proposed cutbacks be determined? To what extent does the proposed budget allow for the initiation of new missions that are not already in the queue?
- If the directorate were to receive more funding than that in the proposed FY07 budget, what would be the first projects to be restored?
- Are there any changes you would like to see in the National Academies Decadal Survey process to help you now or in the years ahead?

Questions for Dr. Fran Bagenal

- What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?
- Do you believe the decisions NASA has made concerning which missions to defer or cancel are consistent with the most recent National Academies Decadal Survey that you released? Have there been any developments since the Decadal Survey that need to be taken into account, and has NASA considered those? Given the FY07 budget request, do you see any need to update the most recent survey or to change the process for the next Decadal Survey?
- How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY07 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?

Questions for Dr. Wes Huntress

- What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?
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- How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY07 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?

Questions for Dr. Berrien Moore

- What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?
- Do you believe the decisions NASA has made concerning which missions to defer or cancel are consistent with the interim report of the National Academies Decadal Survey that you released? Given the FY07 budget request, do you see any need to change the process for the next Decadal Survey?
- How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY07 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?

Questions for Dr. Joseph H. Taylor, Jr.

- What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?
- Do you believe the decisions NASA has made concerning which missions to defer or cancel are consistent with the most recent National Academies Decadal Survey that you released? Have there been any developments since the Decadal Survey that need to be taken into account, and has NASA considered those? Given the FY07 budget request, do you see any need to update the most recent survey or to change the process for the next Decadal Survey?
- How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY07 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?

Chairman BOEHLERT. The hearing will come to order.

I want to welcome everyone here this morning to our hearing on what is probably the most controversial and problematic aspect of NASA's proposed fiscal year 2007 budget, funding for its Science Mission Directorate. This morning's hearing is the first time that leading scientists and NASA have been together to have a public discussion of the proposed budget and its potential impacts. And we have before us today the perfect panel for that discussion: the head of NASA science and representatives of each of the four decadal surveys in which scientists agreed on a list of priorities for NASA funding. This is exactly the kind of interaction the Science Committee was created to foster.

And our goal here this morning is to have a genuine conversation. I want to encourage as much give-and-take among the panel as possible. We have brought you together to hear not only what you have to say to us but what you have to say to each other. So I encourage you to engage your fellow panelists and to raise issues that you want each other to address.

The model here is the hearing we had on the Hubble servicing mission, which I am sure Dr. Taylor remembers well and fondly, I hope.

That is not to say that we don't have plenty of questions of our own. We want to understand exactly what is at stake if we reduce funding for science, as NASA has proposed. Let me emphasize that I am not just talking about hearing what is canceled or deferred. We need to know why doing something a few years later would make a difference. But perhaps most important, we need to hear whether, given the proposed level of funding, NASA has made the right choices about what to cancel or defer.

In the written testimony, all four of our non-NASA witnesses indicated that NASA has gotten it wrong by trying to preserve flagship missions while cutting smaller missions and research grants because of the impact that will have on retaining and attracting scientists to the field. I want to pursue this issue thoroughly. Both NASA and the Congress need to have a better understanding of how to balance whatever cuts are made to assure the future of space science and Earth science.

My goal today is to have an in-depth, informed discussion on the particulars of what NASA has proposed and of what research scientists are pursuing, not just to hear that everyone would like to have more money. I think we can stipulate that every person on the panel, including Dr. Cleave, would like to see more money for science. That is a given. Boy, I will sign up for that. What we need to understand is what would be lost if more money does not go to science, and again, even more importantly, what we should do if more money is not available or if only a little more money is available. That is what will make this hearing valuable and enable it to move our decision-making process forward.

I say that as a strong supporter of NASA's science programs. I have laid out my position pretty clearly in the past few weeks, so I won't take much time to do it again now. Let me just say that I see science as the most successful aspect of NASA, one that expands the human mind, excites students, pushes technology, provides vital information about our own planet, and helps make the

United States a world leader. I want to do everything in my power to protect NASA science, but to do so, what I need this morning is information, not rhetoric.

We have before us sort of a "dream team" for that purpose, and I look forward to hearing from all of you.

[The prepared statement of Chairman Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD L. BOEHLERT

I want to welcome everyone here this morning to our hearing on what is probably the most controversial and problematic aspect of NASA's proposed fiscal 2007 budget—funding for its Science Mission Directorate. This morning's hearing is the first time that leading scientists and NASA have been together to have a public discussion of the proposed budget and its potential impacts.

And we have before us today the perfect panel for that discussion—the head of NASA science and representatives of each of the four decadal surveys in which scientists agreed on a list of priorities for NASA funding. This is exactly the kind of interaction the Science Committee was created to foster.

And our goal here this morning is to have a genuine conversation. I want to encourage as much give-and-take among the panel as possible; we've brought you together to hear not only what you have to say to us, but what you have to say to each other. So I encourage you to engage your fellow panelists and to raise issues that you want each other to address. The model here is the hearing we had on the Hubble servicing mission, which I'm sure Dr. Taylor remembers well—and fondly, I hope.

That's not to say that we don't have plenty of questions of our own. We want to understand exactly what is at stake if we reduce funding for science as NASA has proposed. Let me emphasize that I'm not just talking about hearing what's canceled or deferred; we need to know why doing something a few years later would make a difference.

But perhaps most important, we need to hear whether, given the proposed level of funding, NASA has made the right choices about what to cancel or defer. In the written testimony, all four of our non-NASA witnesses indicate that NASA has gotten it wrong by trying to preserve flagship missions while cutting smaller missions and research grants because of the impact that will have on retaining and attracting scientists to the field. I want to pursue that issue thoroughly. Both NASA and the Congress need to have a better understanding of how to balance whatever cuts are made to ensure the future of space science and Earth science.

My goal today is to have an in-depth, informed discussion on the particulars of what NASA has proposed and of what research scientists are pursuing, not just to hear that everyone would like more money. I think we can stipulate that every person on the panel, including Dr. Cleave, would like to see more money for science. What we need to understand is what would be lost if more money does not go to science and, again, even more importantly what we should do if more money is not available or if only a little more money is available. That's what will make this hearing valuable and enable it to move our decision-making process forward.

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We have before us a sort of "dream team" for that purpose. And I look forward to hearing from all of you.

Chairman BOEHLERT. And now it is my pleasure to recognize the Ranking Member, Mr. Gordon of Tennessee.

Mr. GORDON. Thank you, Mr. Chairman.

I, as usual, concur with your concern about the future of our NASA science program, and I am glad we do have such a good panel here to discuss it.

I do feel compelled to share one concern that I am sure Dr. Ehlers would share with me, too, and that is that NASA seems to be taking a devious new approach to dealing with Congress and

with the public. And that is, they send us likable, knowledgeable individuals up here that give open and honest answers and admit the problems that they face. That is very clever, but we still have to do our job here.

So today's hearing is focused on two important components of NASA's overall science enterprise: its space and Earth science programs. Those programs have generated many of the discoveries, imagery, and inspiration that have engaged the American public in the excitement and wonder of space exploration.

Moreover, NASA's science programs have helped to nurture and develop successive generations of scientists and engineers through university-based research, participation in space science missions, and data analysis.

In addition, NASA's science programs have long been marked by the high degree of productive international cooperation and collaboration. In other words, NASA's science programs have amply demonstrated the wisdom of the Nation's investment in them.

In that regard, when the President announced his Exploration Initiative two years ago, we were promised a robust science program at NASA with a healthy annual funding rate and an impressive set of future missions. As we know, that has not happened.

In the two years since the fiscal year 2005 budget request was submitted, the Administration has cut more than $4 billion from the funding plans of NASA's space, Earth, and science programs.

In addition, while not the focus of today's hearing, I would also point out that NASA's life science and microgravity research programs have been decimated over the last two years, and funding for the ISS research has been cut back to the point where it is unclear exactly what use NASA intends to make of the ISS.

Returning to NASA's space and Earth science programs, let me take a moment to list some of the impacts of the proposed reductions. Namely, the fiscal year 2007 budget request would cut funding for research and analysis, the funding that helps support university-based space and Earth science research by $350 to $400 million over the next five years, including a 50-percent reduction in fundamental research in astrobiology.

The Explorer program would be cut, and researchers working on a competitively selected Small Explorer mission would have their mission canceled for budgetary reasons without even prior review. Funding for robotic exploration of the solar system would be cut significantly relative to what had been projected just two years ago.

NASA's planet finding program, which was featured prominently in the President's Exploration Initiative, is in disarray as a result of this budget request. The SOFIA mission being developed jointly with Germany, while officially "under review," is given no funding in the fiscal year 2007 budget request. The Beyond Einstein Initiative would be delayed indefinitely.

The GPM mission, one of the highest scientific priorities of the Earth science research community, would be delayed two and a half years. I could go on, but you get the picture.

And as some of our witnesses will point out in their testimony, these proposed actions run directly counter to the spirit and intent of the President's own American Competitiveness Initiative.

In fairness, the NASA Administrator has said that he is not happy about the need to make cuts in the science programs, but he characterizes the cuts as "just a temporary situation that will be corrected when the Shuttle is retired." I would like to believe that he is right, however, I am afraid I cannot share his confidence and optimism based on the facts at hand.

We have already seen that for the past two years this Administration has been unwilling to fund NASA at the levels that it said NASA would need. And over those same two years, NASA has shifted billions of dollars out of its space and Earth science programs. I hope the Associate Administrator can give me credible assurances that that won't happen again next year or the year after.

At the same time, as the Shuttle program is ending in 2010, NASA plans to call for a major increase in funding requirements for its Exploration Initiative to pay for the heavy launch vehicle, the lunar lander, and other exploration-related hardware programs. It looks like any Shuttle dividend will be going to fund human exploration, not to cover science funding shortfalls. I hope I am wrong, and I hope that Dr. Cleave will be able to shed some light on the plans for science funding beyond this budget request.

And despite the President's call for an integrated program of human and robotic exploration of the solar system, I am concerned that science has become an afterthought in the Agency's Exploration Initiative, largely decoupled from the Exploration Initiative and vulnerable to being cut back, as necessary, to pay for the human exploration hardware. That worries me, and I hope that Dr. Cleave will clarify the role that her office is playing in determining the scientific priorities that NASA will pursue in its Exploration Initiative. Maximizing the Nation's scientific return should be a prime determinant of NASA's approach to human exploration and not an after-the-fact justification.

But we have a great deal to discuss today, and I—and a distinguished set of witnesses to help us sort through these tough problems.

So once again, I welcome you all.

And I yield back the balance of my time.

[The prepared statement of Mr. Gordon follows:]

PREPARED STATEMENT OF REPRESENTATIVE BART GORDON

Good morning. I want to welcome the witnesses to today's hearing.

Today's hearing is focused on two important components of NASA's overall science enterprise—its space and Earth science programs. Those programs have generated many of the discoveries, imagery, and inspiration that have engaged the American public in the excitement and wonder of space exploration.

Moreover, NASA's science programs have helped to nurture and develop successive generations of scientists and engineers through university-based research, participation in space science missions, and data analysis.

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In that regard, when the President announced his exploration initiative two years ago, we were promised a robust science program at NASA with a healthy annual funding rate and an impressive set of future missions. As we now know, that's not what happened.

In the two years since the FY 2005 budget request was submitted, the Administration has cut more than $4 billion from the funding plans for NASA's space and Earth science programs.

In addition, while not the focus of today's hearing, I would also point out that NASA's life science and microgravity science research programs have been decimated over the last two years and funding for ISS research has been cut back to the point where it is unclear exactly what use NASA intends to make of the ISS.

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And despite the President's call for an integrated program of human and robotic exploration of the solar system, I am concerned that science has become an afterthought in the Agency's exploration initiative—largely decoupled from the exploration initiative and vulnerable to being cut back as necessary to pay for the human exploration hardware.

That worries me, and I hope that Dr. Cleave will clarify the role that her office is playing in determining the scientific priorities that NASA will pursue in its exploration initiative. Maximizing the Nation's scientific return should be a prime determinant of NASA's approach to human exploration, not an after-the-fact justification.

Well, we have a great deal to discuss today, and a distinguished set of witnesses to help us sort through some tough issues. I again want to welcome them, and I yield back the balance of my time.

Chairman BOEHLERT. The Chair is pleased to recognize the distinguished Chair of the Subcommittee on Space and Aeronautics, Mr. Calvert.

Mr. CALVERT. Good morning. Mr. Chairman, I would like to welcome Dr. Cleave and welcome her aboard and the rest of the distinguished witnesses today and look forward to hearing their testimony. Today's panel is certainly quite impressive with its wide range of scientific backgrounds. Our nation is lucky to have such

distinguished advisors for the direction that Earth sciences should take, and we certainly thank all of you for your service.

Last 4th of July, I went to the Jet Propulsion Laboratory to see the Deep Impact as it collided with a comet. I certainly looked in awe at the pictures that we were getting from the Hubble Space Telescope. I have watched news programs showing our Mars rovers just keep on going. This is what great nations do: explore. And we must keep it up—these investments in exploration in science and in aeronautics.

We are certainly aware that NASA Administrator Mike Griffin is overseeing the delicate balance of the programs within his portfolio. Although the Administration is operating in a—certainly a tight budget environment, 2007 NASA did receive a small increase over the fiscal year 2006 level. Now that Congress has legislative endorsement for the *Vision for Space Exploration* in our NASA authorization bill of 2005, we must begin funding this program and its crew exploration vehicle at certainly an efficient level.

We are all aware of the need to keep our nation competitive. NASA is an important part of the investment that our country must make to keep us at the leading edge. While we may not like the fact that the available resources that allow the science programs at NASA to be funded only at a 1.5 percent increase, this important sector of NASA budget is still about one-third of its total budget. This is a lean budget year, and we must maximize every penny.

With the guidance of those scientists from the National Academies, I am confident that we are investing in the science that is most important to this country and to the world. I look forward to hearing from Dr. Cleave and our distinguished panel on how we will keep the United States at the forefront scientifically.

With that, Mr. Chairman, I yield back the balance of my time.

[The prepared statement of Chairman Calvert follows:]

PREPARED STATEMENT OF CHAIRMAN KEN CALVERT

Mr. Chairman, I welcome Dr. Cleave and the rest of our distinguished witnesses today and look forward to hearing their testimony. Today's panel is quite impressive with its wide range of scientific backgrounds. Our nation is lucky to have such distinguished advisers for the direction that our sciences should take. We thank you for your service.

Last Fourth of July, I went to the Jet Propulsion Laboratory to see Deep Impact as it collided with a comet; I have looked in awe at the pictures that we are getting from the Hubble Space Telescope; I have watched news programs showing our Mars rovers just keep going. This is what great nations should do—explore! We must keep up these investments—in exploration, in science, and in aeronautics.

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This is a lean budget year and we must maximize every penny. With the guidance of those scientists from the National Academies, I am confident that we are investing in the science that is most important to this country and to the world. I look

forward to hearing from Dr. Cleave and our distinguished panel on how we will keep the United States at the forefront scientifically.

Chairman BOEHLERT. Thank you very much, Mr. Chairman.

The Chair is pleased to recognize the distinguished gentleman from Colorado, the Ranking Member of the Subcommittee, Mr. Udall.

Mr. UDALL. Thank you, Mr. Chairman.

Good morning. I want to welcome all of you to the panel today and particularly acknowledge Dr. Bagenal who is here from the University of Colorado, which I am proud to represent.

I want to be brief, as have been all of my colleagues, because we want to hear from you today, but I did want to make a couple of points.

Many have referred to NASA's science programs as the crown jewels of NASA, and I think that is an apt characterization. The science activities of NASA, whether they involve missions to Pluto, scientific satellites observing the Earth, space-based observatories peering out to the farthest reaches of the universe, or researchers at university labs working on space, Earth, and life sciences research all have the potential to advance our knowledge, inspire our youth, and improve the quality of life here on Earth.

That is not to say human exploration is not important. I think all of us, and I do, in particular, support an integrated program of human and robotic exploration. It makes good sense, and it will deliver many benefits to all of us over the long run.

But we are not off to a good start when billions of dollars are cut from NASA's science programs within the first two years of the President's Initiative. Even more troubling is the fact that some of these cuts are damaging the university-based research that is critical to train the next generation of scientists and engineers.

At our recent hearing with Dr. Griffin, he stated that he had asked Dr. Cleave to review the proposed research and analysis cuts. And hope today, Dr. Cleave, that you may be able to report on the status of that review.

I would like to, in closing, though, make my position clear. I believe that those R&A cuts are ill-advised, and I intend to work with my colleagues to correct the situation as Congress considers the NASA funding request.

To use another analogy, in many respects, NASA's science programs are the Agency's intellectual seed corn. The fiscal year 2007 budget puts that seed corn at risk, and I think that is a mistake.

We have a thoughtful set of experts whose testimony will be very helpful to us as we grapple with the implications of NASA's budget plan.

Thanks again for your participation.

And Mr. Chairman, if I have any time left, I would like to yield it back.

[The prepared statement of Mr. Udall follows:]

PREPARED STATEMENT OF REPRESENTATIVE MARK UDALL

Good morning. I'd like to join my colleagues in welcoming the witnesses to today's hearing, and I'm pleased to see that Dr. Fran Bagenal from the University of Colorado is part of the distinguished panel that will be testifying today. Welcome to all of you.

I will be brief in my remarks, because I believe that much of the prepared testimony echoes the concerns that I have about the direction NASA is headed.

Some have referred to NASA's science programs as NASA's "crown jewels." That's an apt characterization.

NASA's science activities—whether they involve missions to Pluto, scientific satellites observing the Earth, space-based observatories peering out to the farthest reaches of the universe, or researchers at university labs working on space, Earth, and life sciences research—all have the potential to advance our knowledge, inspire our youth, and improve the quality of life here on Earth.

That is not to say that human exploration is not also important—I strongly support an integrated program of human and robotic exploration. It makes good sense, and it will deliver many benefits to the Nation over the long run.

However, we are not off to a good start when billions of dollars are cut from NASA's science programs within the first two years of the President's exploration initiative.

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The FY 2007 budget request puts that "seed corn" at risk, and I think that's a mistake.

Well, we have a thoughtful set of experts whose testimony will be very helpful to us as we grapple with the implications of NASA's budget plan.

I want to thank them for their participation, and I look forward to hearing their testimony. I yield back the balance of my time.

Chairman BOEHLERT. You are very gracious. Thank you very much, and we will accept that.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. I want to thank the witnesses for appearing before the Committee to review the proposed fiscal year 2007 (FY07) budget for the Science Mission Directorate of the National Aeronautics and Space Administration (NASA), and to examine how that budget would affect research in space science and Earth science.

The Science Mission Directorate supports research in four major areas: Solar System Exploration or Planetary Sciences, Astrophysics, Heliophysics, Earth Sciences. The valuable research has helped improve our knowledge and create new capabilities leading to advances in weather forecasting, storm warnings, and natural resource management.

Each area of the Science Mission Directorate will see major cuts in the FY07 budget. These budget reductions have led NASA to delay, cancel or scale back most Earth science missions. NASA does not appear to have sufficient funds to launch some of the missions that it describes as being on schedule. Furthermore, NASA has few if any additional Earth science missions in the planning pipeline beyond the missions that have been in the works for years. If one of NASA's primary roles in the Earth sciences program is to build and launch research satellites to provide a deeper understanding of the basic processes governing the Earth's physical system, I am skeptical of NASA's ability to operate a successful Earth science program that lives up to its objectives. I would like to know what should be done to address the concerns expressed over the direction of NASA's Science Mission Directorate. Finally, it would be useful to find out what approach NASA took to determine the priority of each of its science programs in order to allocate the limited available funding among its agency.

Again, I thank the witnesses for appearing today and look forward to their testimony.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman and Ranking Member. Welcome to today's witnesses.

I always like to point out how important NASA is to Texas. Since we are discussing NASA's Science Mission Directorate, I would also like to again remind everyone of the great number and variety of benefits NASA research has yielded.

The all-important computer mouse originated from NASA research.

NASA engineers pioneered cochlear implants to restore the ability to hear.

NASA satellites track hurricanes, wildfires and volcanoes.

NASA research has led to safer highways and better airplanes.

NASA research has led to a greater understanding of Attention Deficit Disorder in children.

NASA has even helped the wine industry determine best areas of a vineyard.

NASA research stimulates the Texas economy and our national research enterprise.

I am concerned that shifting priorities and moving targets are creating challenges for NASA. The Agency needs stability to be able to accomplish its mission effectively.

It is my hope that the Agency will gain the stable funding it needs to carry out a strong scientific research program now and plan to meet future challenges.

Thank you, Mr. Chairman. I yield back.

[The prepared statement of Mr. Honda follows:]

PREPARED STATEMENT OF REPRESENTATIVE MICHAEL M. HONDA

I thank Chairman Boehlert and Ranking Member Gordon for holding this important hearing today, and I thank our distinguished witnesses for making the time to be here.

I remember when Administrator Griffin said that the President's space exploration program would not cost science a thin dime, and looking at this budget, I have to marvel at how things have changed. The future of scientific activities within NASA, be it the science that falls within the Science Mission Directorate or that which supports exploration within the Exploration Systems Mission Directorate, looks bleak.

Funding that was projected to grow 7–8 percent annually in last year's budget request only increases by 1.5 percent in this request, and the prospects for the future are sub-inflationary increases in the outyears. Overall, approximately $3 billion is being cut from NASA's science programs over the period FY06–10 relative to what had been assumed in last year's budget request for those years.

At our hearing two weeks ago I asked Administrator Griffin about the review of the Stratospheric Observatory for Infrared Astronomy (SOFIA) called for in the budget request. He told us that there were concerns about the airworthiness of the airplane in which the telescope is to be mounted. I have since learned that this airplane is ready to proceed with flight testing, so I find his answer unsatisfactory, and I intend to pursue the matter further here today.

Other concerns I have surround the cancellation of the NuSTAR Explorer mission, and the cuts faced by the Explorer program overall. I am also troubled by the decision to terminate the Deep Space Climate Observatory, which contributes not only to climate and climate change research but also to our understanding of the solar wind, which will have significant impacts on humans taking part in a mission to Mars. And Astrobiology is cut by 50 percent, more than all other programs within the Research and Analysis budget.

These are but a few of the programs that this budget shortchanges, all in the name of extending tax cuts for the wealthiest Americans. At a time when the President is hyping a competitiveness initiative and trying to attract students to science and engineering, NASA is sending the message that it is an unreliable partner to the research and university communities, driving potential students away from fields that they cannot trust will still be viable in the coming years.

I continue to disagree with the short range view NASA is taking to implement a very long range program, setting aside important scientific work to rush the development of a vehicle which I do not believe can be designed properly without some of the knowledge to be gathered by that science.

[The prepared statement of Ms. Jackson Lee follows:]

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

Chairman Boehlert, Ranking Member Gordon, thank you for organizing this important hearing to discuss the impacts of the FY07 budget proposal on NASA's science mission directorate. I also want to welcome our distinguished panel of witnesses—Dr. Mary Cleave, Dr. Fran Bagenal, Dr. Wesley Huntress, Dr. Berrien

Moore, and Dr. Joseph Taylor—and thank their for coming before our committee this morning.

As a long time Member of House Science Subcommittee on Space and Aeronautics, as well as a Representative of the 18th Congressional District in Houston—home of the Johnson Space Center—I wholeheartedly support the work of NASA. I would like to congratulate NASA on their work and past successes, for which there are many. I firmly believe that the investment we make today in science will pay large dividends in the future. Similarly, I do not want to put a cap on the frontiers of our discovery, NASA should aim high and continue to push our nation at the forefront of space exploration.

TABLE: NASA Five Year Science Mission Directorate Funding Plan
(Budget Authority in Millions)

Account	FY2006 Op. Plan	FY 2007 Request	FY 2008 Request	FY 2009 Request	FY 2010 Request	FY 2011 Request
Solar System Exploration	1,582.3	1,610.2	1,598.6	1,840.4	1,899.6	1,846.7
The Universe	1,507.9	1,509.2	1,500.9	1,307.9	1,276.1	1,309.7
Earth-Sun System	2,163.5	2,210.6	2,283.7	2,288.9	2,315.8	2,390

NASA CUTS

Unfortunately, this President's own budget does not meet the demands of his ambitious agenda. Two years after the Administration laid out a five-year funding plan for NASA that was intended to demonstrate the affordability, sustainability and longevity of the exploration initiative. Now, the Administration proudly presents us with this funding plan that under funds the original request by over $4 billion for space and Earth science.

SOFIA PROJECT

I am particularly concerned about the Stratospheric Observatory for Infrared Astronomy project, known as SOFIA. The SOFIA system will house a high power telescope to a Boeing 747 aircraft to allow us to see in to the depths of space. The SOFIA development is 85 percent complete. U.S. funds invested in industry contracts to-date are about $500 million. The work on SOFIA is being conducted in my home state of Texas. Given that SOFIA is almost complete and has cost the American taxpayers several hundred million dollars to date, how would NASA explain to taxpayers that it would be better to abandon the project now without at least completing it and finding someone to operate it going forward?

Dr. Mae Jemison Grant Program

I would also like to talk about a very important amendment I added to the NASA Authorization bill recently passed. The amendment requires the Administrator to establish the Dr. Mae Jemison Grant Program to work with Minority Serving Institutions to bring more women of color into the field of space and aeronautics. This committee has met several times over the last month, and everyone agreed on the dire need to attract more people to the scientific fields. I am looking forward to see how this Grant Program will unfold. There was no money in the authorization bill for the program, and I hope, with your encouragement we can together fight for funding in the FY07 appropriations bill. Attracting and harnessing the talents of minorities into the sciences is an absolutely vital pursuit.

Conclusion

The President stated that the fundamental goal of his directive for the Nation's space exploration program is ". . .to advance U.S. scientific, security, and economic interests through a robust space exploration program." I could not agree more with that statement. As Members of this committee know, I have always been a strong advocate for NASA. *My criticism of the President's budget and its relation to the vision for NASA is intended only to strengthen our efforts to move forward as we always have in the area of space exploration and discovery.* NASA possesses an exciting opportunity to charter a new path that can lead to untold discoveries. As always

I look forward to working with the good men and women of NASA as we continue to push the boundaries of our solar system.

Chairman BOEHLERT. We have one panel today, and a very distinguished panel it is.

But before introducing the panel, I want to acknowledge a transition. In our audience today, we are pleased to have Marcia Smith, who, this week, completed 30 years of service in the Congressional Research Service. She was a fountain of information and just wonderful and very able in serving this committee in terms of a source of information. She is now the Director of the Space Studies Board at the National Research Council. Ms. Smith, I am glad to have you here. Thank you so much for your past service, and we look forward to continued information flowing from you as part of my continuing education program.

Now our panel of witnesses. Dr. Mary Cleave, Associate Administrator at NASA for the Science Mission Directorate. And I hope you observed from the opening statements that you have got a cheerleading squad up here that likes what you are doing. Dr. Joseph H. Taylor, Jr., Co-Chairman of the National Academy of Sciences Decadal Survey for Astrophysics, "Astronomy and Astrophysics in the New Millennium." Dr. Taylor is a Nobel Laureate and distinguished professor of physics at Princeton University. Dr. Taylor. Dr. Fran Bagenal is a Member of the National Academy of Sciences Decadal Survey for Sun-Earth Connections, "The Sun to the Earth and Beyond." Dr. Bagenal is a professor of astrophysical and planetary sciences at the University of Colorado at Boulder. Dr. Bagenal. Dr. Wes Huntress is a Member of the National Academy of Sciences Decadal Survey for Solar System Exploration, "New Frontiers in the Solar System." Dr. Huntress is the Director of the Geophysical Laboratory at the Carnegie Institution of Washington and was Associate Administrator for Space Science at NASA from 1992 to 1998. Dr. Huntress. Dr. Berrien Moore is the Co-Chairman of the National Academy of Sciences Decadal Survey for Earth Sciences, "Earth Observations from Space: A Community Assessment and Strategy for the Future." Dr. Moore is the Director for the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire. Dr. Moore. And Congressman Bass made sure that I acknowledged you in the right way, so it is good to have you here.

Dr. Cleave, you are first up. And don't get disturbed by the clock. I am always offended by the fact that we expect you to summarize in 300 seconds or less everything you want to tell us. So we are going to run the clock to sort of guide you, and when the red light comes on, that means that you should begin to think in terms of wrapping it up. But we are pleased to have you here, Dr. Cleave. You are up first.

STATEMENT OF DR. MARY L. CLEAVE, ASSOCIATE ADMINISTRATOR, SCIENCE MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. CLEAVE. Mr. Chairman, Members of the Committee, thank you for the opportunity to appear today to discuss NASA's science program and our plans as represented in the President's 2007 budget request for NASA.

The past year has been a very significant one for us at NASA, and we would like to begin by highlighting just a few of the things that we have been able to do this year. With ICEsat we track significant changes in the Arctic sea ice extent, and GRACE satellite has made the first direct comprehensive mass survey of the Greenland ice sheet.

We have Voyager I spacecraft, which has entered the vast turbulent expanse of the heliosheath, about 8.7 billion miles from the sun, and that is where no human-made object has ever traveled before. The Hubble Space Telescope continues a successful mission of discovery and exploration. And among its many achievements, there was a discovery that Pluto may have three moons and offering more insights into the nature and evolution of the Pluto system and Kuiper Belt.

We also launched New Horizons to Pluto, and that will take nine years to arrive, and when it does, we will be able to study those new moons.

We have a lot more, but we will just limit it to that.

In your letter, you asked me that I explain the budget request for the Science Mission Directorate, so I will attempt to do that now.

NASA's fiscal year 2007 budget request provides about $5.3 billion for the Agency's science portfolio to explore the universe, solar system, and the Earth. NASA's science budget is moderated to a 1.5 percent growth for fiscal year 2007, and then it would be compared—that is compared to fiscal year 2006, and then will have one percent growth thereafter through fiscal year 2011.

As Administrator Griffin testified on February the 16th, the decision to slow the rate of growth in NASA's science mission is a matter of how the Agency will use the available resources within the NASA portfolio. Administrator Griffin has given me a charge, however, which is to deliver a robust and executable program that can be implemented in this resource-constrained environment. By "executable," I mean that we will be selecting, developing, and launching a slate of science missions that will be within the cost and schedule targets. So we are going to be monitoring everything very carefully.

The rebalanced portfolio ensures that we maintain a suite of missions in all phases of development in each science discipline.

We also, within each science area, are working to try to assure a mix of investments between missions and R&A that will ensure that we provide support for both future scientists and engineers, because this business takes a good balance of both of those.

We would like to highlight some of the changes within our science portfolio, and a detailed description of the fiscal year 2007 budget is in the written testimony.

For astrophysics, in 2007, we are requesting $1.5 billion. This budget will enable NASA to continue to operate Hubble and supports a servicing mission in 2007 through 2008 depending on the final outcome of the second Shuttle return to flight. The James Webb Space Telescope will continue to progress and is entering the development phase as a result of the recent replanning effort to address cost gross.

NASA, in conjunction with the German Aerospace Center, DLR will conduct a review of SOFIA over the next several months to determine whether NASA will continue this project. The results of this study will be incorporated in the fiscal year 2007 budget at a later date, if necessary, via an operating plan.

Within the 2007 Earth science budget, we requested $1.5 billion. With the Earth Observing System initial series of satellites now deployed and the focus is on exploiting the data in research, modeling, and applications, and on refining, formulating, and implementing successor and complementary missions, such as Glory, NPP, and the ESSP missions OCO and Aquarius.

I am pleased to announce that we did publish a synopsis for the Data Continuity Mission, which we will be conducting with the U.S. Geological Survey and consistent with the guidance from OSTP. And we released that this week. We are trying to move on that one as rapidly as possible.

The release of the next ESSP Announcement of Opportunity within Earth science will be no earlier than fiscal year 2008. We formed a working group with NOAA to plan the transition of NASA research results and observing capabilities to future NOAA operational missions, and we will report to you on those results. And we are eagerly awaiting the National Academy of Sciences Decadal Survey this fall to help us guide our planning in Earth science. We have never done one before, and we think it will be extremely helpful.

In the heliophysics budget for 2007, we have requested $679.9 million. Three Living with a Star projects will be supported: the SDO, Solar Dynamics Observatory, Radiation Belt Storm Probe, and also the Space Environment Testbed. The third STP, STEREO mission will be—is scheduled to launch two spacecrafts to study the sun later this year. We also have a Magnetosphere Multi-Scale mission, which is a fourth STP mission, and its scientific goals were identified as the highest priority in the 2003 National Research Council Decadal Study, and that will enter formulation phase this year. Heliophysics is the host of the Explorer Announcement of Opportunity, which actually goes across divisions. Its next Announcement of Opportunity will be in fiscal year 2008.

Within planetary science, we have requested $1.6 billion to fund new missions to the solar system bodies and maintain the Deep Space Network. The Mars program in the fiscal year 2007 President's budget is still an aggressive one and will launch every optimal orbital opportunity. We have the Mars Reconnaissance orbiter orbit insertion at Mars that is coming up next week. This will be followed by a Phoenix launch in 2007, Mars Science Laboratory in 2009 and a Mars Scout in 2011. The AO for the 2011 Mars Scout is planned for release in April 2006 with proposals due in July of 2006. Subsequent missions are being outlined in a community roadmapping activity now undergoing review by the National Academies.

The next Discovery Announcement of Opportunity was released in January with proposals due in April of 2006 and selection expected in the fall of 2006. We also have a second New Frontiers mission, Juno, that is included in this new budget. And the next New Frontiers AO is planned for no earlier than fiscal year 2008.

So that covers all of our divisions. I would like to address first the reduction in research and analysis funding, which I know everyone is concerned about——

Chairman BOEHLERT. Dr. Cleave, and I would hope you could do that, because what you have just told us so far is what we already know.

Dr. CLEAVE. Okay.

Chairman BOEHLERT. Okay. So—but if you could begin to think in terms of wrapping up.

Dr. CLEAVE. Okay.

The research in R&A, we are trying to maintain a balance with our science and engineering work forces. However, we have agreed that we will work with the community. Administrator Griffin has committed to us working with the community in order to provide an ops plan change, if that is deemed. Within each division, it could be different. So we are really trying to work on that at the current time.

We do find that interaction with the community is vital to our approach in science. It is really their science program. We try to be responsive to their needs, and we always need their input.

Thank you.

[The prepared statement of Dr. Cleave follows:]

PREPARED STATEMENT OF MARY L. CLEAVE

Mr. Chairman and Members of the Committee, thank you for this opportunity to appear before you today to discuss NASA's Science program and our plans as represented in the President's FY 2007 budget request for NASA.

The past year has been one of significant achievement for NASA's science missions. The Voyager 1 spacecraft entered the vast, turbulent expanse of the heliosheath, 8.7 billion miles from the sun, where no human-made object has traveled before. The Hubble Space Telescope continues its successful mission of discovery and exploration. Among its many achievements was the discovery that Pluto may have three moons, offering more insights into the nature and evolution of the Pluto system and Kuiper Belt. Through coordination of observations from several ground-based telescopes, NASA's Swift spacecraft and other satellites, scientists solved the 35-year-old mystery of the origin of powerful, split-second gamma-ray bursts. Using data from NASA's Aura satellite, NASA and National Oceanic and Atmospheric Administration (NOAA) researchers found they could improve the accuracy of six-day forecasts by up to six hours. The ICEsat tracked significant changes in Arctic sea ice, and the GRACE satellite made the first direct comprehensive mass survey of the Greenland ice sheet. Deep Impact traveled 268 million miles to meet comet Tempel 1, sending its impactor to collide with the comet and providing researchers with the first look inside a comet. The Mars twin rovers continue studying the harsh Martian environment, well beyond their expected mission life. Among its many achievements, Cassini has taken spectacular images of Saturn, its rings, and its amazing variety of moons. The European Space Agency's Cassini-Huygens probe successfully descended through the murky atmosphere of Saturn's largest moon, Titan, revealing some of its "Earth-like" features. The Mars Reconnaissance Orbiter (MRO) successfully launched, and, next week, will go into orbit around Mars, providing high resolution imagery of the Martian surface and more data than all previous planetary missions combined. MRO will zoom in for extreme close-up photography of the Martian surface, analyze minerals, look for subsurface water, trace the amount of dust and water in the atmosphere, and monitor the daily global weather. And on January 19, 2006, the New Horizons mission successfully launched, beginning its nine-year journey to Pluto. We are now looking forward to the upcoming launches of New Millennium's ST–5, CloudSat and CALIPSO, TWINS–A, CINDI, and STEREO.

FY 2007 Budget Request

NASA's FY 2007 budget request provides $5.33 billion for the Agency's Science portfolio to explore the universe, solar system, and Earth. As Administrator Griffin testified on February 16, the decision to slow the rate of growth for NASA's Science

missions is a matter of how the Agency will use the available resources within the overall NASA portfolio. Thus, NASA cannot afford the costs of starting some new Science missions, like a mission to Jupiter's moon Europa, or the next-generation space astrophysics missions beyond the James Webb Space Telescope (JWST), at this time. It is important to know, however, that NASA is simply delaying these missions, not abandoning them.

The Agency's Science budget has grown much faster than NASA's total budget since FY 1993. In 1992, the Science budget represented 24 percent of the overall NASA budget while today, in the FY 2007 request, 32 percent of the Agency's budget is allocated to Science. NASA's Science budget is moderated to 1.5 percent growth in the FY 2007 budget request, compared with the amount appropriated for NASA in FY 2006 (as reflected in NASA's initial Operating Plan provided to the Committee) and then one percent per year thereafter through FY 2011.

In the FY 2007 budget request, there are some additional budget shifts within the Science portfolio, to adjust the balance of the program to better reflect our science priorities and consistent with the President's FY 2006 Budget Amendment. The resulting portfolio ensures that we maintain a suite of missions in all phases of development in each science discipline. In addition, within each Science area, we are working to assure that the mix of investments between missions and Research & Analysis (R&A) will ensure that we provide support to both future scientists and engineers.

As reflected in the FY 2006 Amendment to the President's Budget, a key aspect of adjusting the balance of the Science program is a significant reduction in the Mars program. This program had been previously slated to grow to $1.3 billion in FY 2010. This aggressive rate of growth had been built into the program over a period of several years. However, given our current budget limitations, had we left the Mars program unchanged, it would have accounted for almost one-quarter of the total Science budget in that timeframe. Maintaining that level of growth in the Mars program would have crowded out too many other high-priority science missions and research activities. We accomplished the reduction largely by deferring the Mars Sample Return mission and human precursor missions. Despite these reductions, the FY 2007 budget request maintains a robust program of Mars exploration, with a mix of orbiting and landed missions being launched at every 26-month opportunity.

The charge that Administrator Griffin has given to me is to deliver a robust and executable program that can be implemented in this resource-constrained environment. By "executable," we mean selecting, developing, and launching a slate of Science missions within cost and schedule targets. I would like to highlight some of the changes within our Science portfolio that will satisfy this directive. First, I would like to note that as part of this reorganization, the Science Mission Directorate will now have four major areas in our portfolio: Astrophysics, Earth Science, Heliophysics, and Planetary Science. The most significant change in this new structure is to break up the Earth-Sun System division into Earth Science and Heliophysics. This change will provide the Earth Science theme with added visibility and better reflects the work being done in these two disciplines. Since the reorganization is not yet final, the new division titles are not reflected in the FY 2007 budget request. My testimony below is based on this new organizational structure.

The FY 2007 **Astrophysics** (previously called Universe) budget request is $1,509 million. This budget supports a Hubble servicing mission in 2007-2008, pending final outcome of the second return-to-flight Shuttle mission. Gamma Ray Large Area Space Telescope GLAST is scheduled to launch at the end of FY 2007, and Kepler has been successfully confirmed for implementation. JWST will continue progress toward entering development phase as a result of a recent replanning effort to address cost growth. The Space Interferometry Mission (SIM), which is planned for launch in 2015/2016, remains in formulation, and the Terrestrial Planet Finder (TPF) mission will be deferred. A review of Stratospheric Observatory for Infrared Astronomy (SOFIA) is being conducted in 2006, to determine whether it is appropriate to continue development of this project. If NASA decides to continue the project, we will incorporate the necessary funds into the FY 2007 budget via the Agency Operating Plan. The NuSTAR mission and the Keck observatory outriggers are canceled. Finally, the Beyond Einstein Program is beginning a process of prioritization, with a goal of selecting a mission (either LISA, Con-X or Joint Dark Energy Mission) to enter development later this decade.

The FY 2007 **Earth Science** (previously part of Earth-Sun System) budget request is $1,530.7 million. With the Earth Observing System initial series of satellites now deployed, the focus is on exploiting their data in research, modeling, and applications, and on defining, formulating and implementing successor and complementary missions. For future missions, the largest challenge remains the deliv-

ery of instruments for the NOAA Polar Operating Environmental Satellite Series (NPOESS) Preparatory Project (NPP). In anticipation of development of a new baseline for NPOESS by the tri-agency Integrated Program Office, NASA has moved the NPP launch date to April 2008; further change is probable as NPOESS rebaselining is still in process. The Glory mission has also been confirmed to proceed to implementation. Launch of the Global Precipitation Measurement (GPM) mission is delayed to the end of 2012. NASA and the U.S. Geological Survey (USGS) received revised guidance from Office of Science and Technology Policy (OSTP) on Landsat, and NASA is proceeding with planning for the acquisition of a Landsat Data Continuity Mission as a free-flyer. In parallel, OSTP will work with NASA, USGS, and other agencies on a strategy for operational land observation. The Earth Systems Science Program (ESSP) Orbiting Carbon Observatory and Aquarius missions have been confirmed to proceed to implementation, and, thus, the ESSP back-up mission Hydros was not confirmed. The release of the next ESSP Announcement of Opportunity will be no earlier than FY 2008. We have formed a joint working group with NOAA to plan the transition of NASA research results and observing capabilities to future NOAA operational systems, and will report on our progress as requested by the Congress. We eagerly await the release of the National Academy of Sciences decadal survey report this fall as a guide to our planning for future Earth Science missions.

The FY 2007 **Heliophysics** (previously part of Earth-Sun System) budget request is $679.9 million. The new Heliophysics Division manages three science flight programs that are funded in the FY 2007 budget request. These are the Solar Terrestrial Probe (STP), Living with a Star (LWS) and Explorer Programs. In addition, the Heliophysics Division will manage the New Millennium Program of technology flight validations. Three LWS projects will be supported in FY 2007. The Solar Dynamics Observatory (SDO) will be near completion of its fabrication phase at the end of this fiscal year, and near initiation of spacecraft integration and test activities. The SDO launch date has been changed from April 2008 to August 2008. The second STP mission, the Radiation Belt Storm Probe (RBSP) project, will be in a formulation phase in preparation for a mission confirmation review, and the Space Environment Testbed (SET) project will be completing payload hardware. The third STP mission, STEREO, is scheduled to launch two spacecraft to study the Sun later this year. The fourth STP mission, the Magnetosphere Multi-Scale (MMS) mission, the scientific goals of which were identified as the highest priority in the 2003 National Research Council decadal study, will also be in formulation phase this year. A Heliophysics Division Explorer program mission, the Interstellar Boundary Explorer (IBEX) project, is expected to be in a hardware construction phase. The plans for launch and operation of AIM and THEMIS, two other Explorer missions managed in the Heliophysics Division, remain unchanged. The release of the next Explorer Announcement of Opportunity (AO) is expected to be no earlier than FY 2008.

The FY 2007 **Planetary Science** (previously called Solar System Exploration) budget request is $1,610 million to fund missions to solar system bodies, and to maintain the Deep Space Network. A key feature within this FY 2007 budget is the further adjustment of the balance of the science portfolio begun last year. The Mars exploration program was slated to grow very substantially in the President's FY 2004 and FY 2005 budget requests. The Mars program in the President's FY 2007 budget request continues to be an aggressive one, with a launch every optimal orbital opportunity. The MRO orbit insertion at Mars is coming up next week. This will be followed by the Phoenix launch in 2007, Mars Science Laboratory in 2009, and Mars Scout in 2011 (the AO for the 2011 Mars Scout is planned for release in April 2006, with proposals due in July 2006). Subsequent missions are being outlined in a community roadmapping activity now undergoing review by the National Academies. Deferred are Mars missions associated with preparation for human missions, in keeping with the planned time frame for human exploration, and a Mars sample return mission. The next Discovery Announcement of Opportunity was released in January 2006, with proposals due in April 2006, and selection expected by fall 2006. The first New Frontiers mission, New Horizons—Pluto, was successfully launched in January 2006. The second New Frontiers mission, Juno, is included in the FY 2007 budget request. The next New Frontiers AO is planned for no earlier than FY 2008. Astrobiology research funding is reduced 50 percent in the President's FY 2007 budget request for several reasons. The lower flight rate for Mars missions, plus the recognition that human exploration missions to Mars are further in the future than previously assumed, has reduced some of the urgency for rapid progress in astrobiology research. The Astrobiology program experienced rapid growth in funding several years ago, and this reduction brings it into balance with the rest of the research program.

The 15 percent reduction in research and analysis (R&A) funding is directly related to slowing rate of growth of Science Mission Directorate (SMD) programs and our desire to maintain a balance in the science and engineering workforces and an adequate number of missions to support them. We understand the concerns regarding these reductions and will work with the community to solicit their input on these programmatic issues. At the recent NASA Advisory Council meeting, the Science Committee requested a review of the R&A program to ensure that it is properly oriented toward the future, and provides adequate funding for younger researchers. We intend to discuss this issue further with the NASA Advisory Council, with representatives of the science community, and the Space Studies Board, and will seek their advice to ensure that we maintain an appropriate mix within each SMD Divisions between R&A, small-, medium-, and large-class missions. Following these discussions, should changes in the mix of R&A and mission investment be necessary, we will pursue that course of action via an adjustment in NASA's initial FY 2007 Operating Plan.

Community Involvement

The Science Mission Directorate (SMD) works continually with the science community to identify the highest science priorities and the best strategies and missions to address those priorities. These suggested priorities are provided through the decadal surveys and other reports of the National Academy of Sciences. We seek advice on implementation of these science priorities via the NASA Advisory Council and subordinate bodies. Implementation plans for each major science area, in the form of "community roadmaps" are developed in a partnership with the science community. During the development phase of major missions, we draw on the science community when needed for assessment of science impacts of potential content or schedule changes, as we did recently with JWST. For operating missions, we seek science community peer review to determine the merits of extending the operation of missions that have exceeded their primary mission lifetimes. After such reviews, NASA has extended the mission operating life of several Earth Science missions including Tropical Rainfall Measurement Mission (TRMM) and Terra, Heliophysics missions such as Solar and Heliospheric Observatory (SOHO) and both Voyager spacecraft, and Astrophysics missions including Chandra and Wilkinson Microwave Anisotropy Probe (WMAP). Dialog with the community will be increasingly important as we move forward to implement their highest priorities in a constrained budget environment.

At the present time, SMD is working to establish a suite of five new advisory subcommittees to the NASA Advisory Council; there will be a subcommittee for each of the four major SMD science areas, and a fifth to provide guidance on planetary protection. Key tasks for the four science subcommittees will be to provide tactical and programmatic advice within the context of National Research Council strategic guidance and to contribute scientific expertise to SMD's long-term program planning efforts.

Interagency/International Cooperation

NASA's science program continues to be broadly international. One example is the MRO spacecraft, due to enter Mars orbit in a week, and carries an Italian-provided radar. The James Webb Space Telescope, one of our flagship astrophysics missions, includes significant contributions from the European Space Agency. And two of our upcoming major launches, the CALIPSO and CloudSat Earth science missions, also feature major foreign collaborations. Carrying on a long-standing practice of annual meetings, we are planning a comprehensive review of cooperative space science activities with the European Space Agency in late June; a comparable Earth science review is also being planned. The Directorate has proposed establishment of a framework for international science cooperation in the exploration context as a theme for discussion at the next biennial meeting of the international Committee on Space Research (COSPAR), to be held in Beijing this coming July.

SMD also works closely with other federal agencies to push the frontiers of science and maximize the science return of our activities. For example, we collaborate with the National Science Foundation (NSF) on astronomy, suborbital, meteorite, and Antarctic research programs. NASA also has a long-standing relationship developing and launching polar-orbiting and geostationary environmental satellites for NOAA. We are currently involved with the Department of Defense, NOAA, and the USGS in remote sensing activities and the development of the next generation of environmental satellites. I am pleased to announce that the synopsis for the Landsat Data Continuity Mission, a collaborative mission between NASA and USGS, was released last week. We also have collaborative agreements in Earth applications with about a dozen Federal government agencies, from the Department

of Agriculture to USGS. Collaborations with domestic and international partners remain an important component in NASA's science programs.

Implementing the Vision for Space Exploration

The human exploration of space beyond low-Earth orbit is a core element of NASA's strategic plan. The fundamental goal of the *Vision for Space Exploration* is *"To advance U.S. scientific, security, and economic interests through a robust space exploration program."* It is the responsibility of SMD, working with the Exploration Systems Mission Directorate (ESMD), to make sure that NASA conducts the science that enables human space exploration, as well as the science that is enabled by human space exploration, in the context of the Agency's and the Nation's overall science priorities.

Within our research programs, SMD supports science that enables human exploration. For instance, within our Heliophysics research program, we are supporting the science required to understand and mitigate the radiation environments that human space explorers will be working in beyond the Earth's magnetosphere, and within our Planetary Science research program we are supporting the study of the Moon, Mars, and other solar system bodies that are the destinations for the human exploration program.

Working with ESMD to realize the science required to enable human exploration of the Moon, SMD is playing a traditional program science role in ESMD's lunar robotic program. ESMD is funding the lunar robotic missions, and SMD is providing scientific advice on instrument selection, development, and related matters. Important aspects of lunar science were addressed in the NRC's recent solar system exploration decadal survey, New Frontiers in the Solar System. At the present time, SMD is working with the NASA Advisory Council on a near-term plan to review and extend these and other identified science priorities that can be addressed on the Moon in the context of the broader science program. This process is expected to also involve the NRC Space Studies Board. Anticipating science opportunities that will be enabled by the lunar human exploration missions, SMD will be evaluating the potential for lunar science. Potential science opportunities enabled by human exploration activities will compete in the same prioritization process as the rest of the SMD science program, since the funds come from the same pool.

Within the zone of intersection between the science and exploration spheres are the choices that will be made on exploration architectures and systems—some choices that are cost neutral for exploration may nevertheless be more beneficial for science. NASA, the NAC, and the Space Studies Board will be undertaking a set of workshops and studies this year to identify science priorities and science opportunities, within the context of the decadal surveys, which will inform such choices. For example we are discussing with the Board the development of a science strategy for the Moon that is consistent with the Board's existing science advice.

Conclusion

In conclusion, NASA faces significant challenges and opportunities in implementing a robust and exciting Science program. In a time of constrained resources and a large number of compelling future Science missions, setting priorities is more important than ever. NASA is committed to undertaking the necessary prioritization studies in a joint activity with the science community via the National Academies and NASA's advisory committee apparatus. Access to the judgment of active members of the research community is absolutely vital in this endeavor, and we are dependent on the continued support and assistance of the broader science and industrial communities and Congress to successfully implement the highest priority programs in a cost-effective manner.

Once again, thank you for the opportunity to testify today. Mr. Chairman and Members of the Committee, I would be pleased to answer any questions that you may have.

BIOGRAPHY FOR MARY L. CLEAVE

Dr. Mary Cleave was appointed as Associate Administrator for NASA's Science Mission Directorate on August 12, 2005. She began her career with NASA in May 1980, at the Johnson Space Center (JSC) when she was selected as an astronaut. Subsequently, she flew two Space Shuttle missions as a mission specialist (STS 61 B in November 1985 and STS 30 in May 1989), logging more than 262 hours in space.

Dr. Cleave joined NASA's Goddard Space Flight Center in Greenbelt, Md. in May 1991 where she worked in the Laboratory for Hydrospheric Processes as the Project

Manager for the Sea viewing Wide Field of view Sensor (SeaWiFS), an ocean color satellite sensor monitoring global marine chlorophyll concentration.

In March 2000, Dr. Cleave moved to NASA Headquarters and joined the Office of Earth Science as the Deputy Associate Administrator for Earth Science (Advanced Planning) where she was responsible for the formulation of NASA's Earth Science activities. After the combination of the Earth and space science directorates at NASA Headquarters in 2005, Dr. Cleave became the Director of the Earth Sun System Division in the Science Mission Directorate.

Dr. Cleave received a Bachelor of Science degree in biological sciences from Colorado State University; a Master of Science in microbial ecology and a doctorate in civil and environmental engineering from Utah State University.

Her awards include two NASA Space Flight Medals; two NASA Exceptional Service Medals; American Astronautical Society Flight Achievement Award; NASA Exceptional Achievement Medal; and NASA Engineer of the Year.

Chairman BOEHLERT. Thank you very much, Dr. Cleave.

Dr. Taylor.

STATEMENT OF DR. JOSEPH H. TAYLOR, JR., CO-CHAIRMAN, NATIONAL ACADEMY OF SCIENCES DECADAL SURVEY FOR ASTROPHYSICS; JAMES S. McDONNELL DISTINGUISHED UNIVERSITY PROFESSOR OF PHYSICS, PRINCETON UNIVERSITY

Dr. TAYLOR. Mr. Chairman, Ranking Minority Member, and Members of the Committee, thank you very much for inviting me to testify. My name is Joseph Taylor, and I am Professor of Physics and former Dean of the faculty at Princeton University.

I will get right to the point.

The most serious impact of the 2007 budget proposal for NASA scientists is that it threatens to diminish astronomical research by a 15 percent cut in the grants line. The Administration has composed a Competitiveness Initiative, and many Members of Congress express support for increased research in the physical sciences, so this reduction seems counterproductive, at best.

The potential damage is compounded, because the cuts will be hardest on youngest members of the community: the assistant professors, the post-doctoral trainees, and graduate students. Many in this group will be forced to turn to other fields. Some will leave the sciences altogether, and other bright, young people will decide not to pursue their training in space science and related fields.

Reductions in the flight rate of NASA's Explorer missions will be especially damaging. These smaller missions have been highly cost-effective, and they often serve as an entry point for younger researchers into mission development and project management. The scientists and engineers who will build tomorrow's great observatories are building today's Explorers. It would be a tragedy to drive these people away from space science.

The budget raises another closely-related issue. The Administration proposes to reduce near-term opportunities so as to fully fund several long-term missions. It calls for termination of a long-planned and nearly completed facility called SOFIA and for indefinite deferral of the Beyond Einstein program. The field of astronomy can sustain itself through lean budgetary times if there is opportunity on the horizon, but this budget proposal sends the message that even nearly-completed missions may never bear fruit. It does not provide the positive view of the future that will keep members of the community engaged.

I believe that Administrator Griffin is trying to follow the recommendations of the Decadal Survey, and I appreciate his efforts to protect the James Webb and the Hubble Space Telescopes in the face of significant cost increases. However, as I mentioned when I appeared before you last year to discuss Hubble, I don't think the highest priority missions should always be pursued without regard to cost or impact on the overall program. The Decadal Survey recommended a mix of large, moderate, and small missions. The 2007 budget is tilted to an unhealthy extent toward the large missions.

We now know that the universe is pervaded by a mysterious dark energy that causes its expansion rate to accelerate. Two years ago, NASA worked with the scientific community to develop a plan synthesizing the Decadal Survey in Astronomy and a follow-up 2003 report into a widely-praised strategy for exploiting these remarkable discoveries. The OSTP led an interagency process that helped NASA, the National Science Foundation, and the Department of Energy to form an implementation plan. The NSF and DOE are proceeding with many of those recommendations, but the 2007 NASA budget pushes its portion into the indefinite future.

NASA and the astronomy community face some very significant budgetary challenges, but I don't think that a new Decadal Survey is desirable now. Of course, science has progressed in five years since the last survey was completed, but the priorities determined then still look about right. A new survey would set an unfortunate precedent and encourage second-guessing in the future.

That said, it is also clear that some sort of advice from the scientific community is needed now. Congress has requested a mid-decade performance assessment for each of NASA's scientific programs. One of the goals is to produce a feasible implementation plan for the rest of the decade. Such a plan would—should form a solid foundation on which to conduct the next Decadal Survey, that is, normal time.

A very important planning prerequisite will be reliable information on costs and risks. We have tried to gather such information when carrying out the last Decadal Survey, but in hindsight, our efforts for NASA projects were clearly inadequate. I believe that NASA must set up a task force to work with Centers and contractors to produce reliable estimates of cost, schedule, and technology risk for each selected mission, including proper contingencies. Serious departures from these projections should be grounds for consideration of cancellation, even for large missions of high priority.

There is no foolproof formula for setting priorities across different scientific disciplines, but it is clear that each of NASA's science programs must remain healthy independently. Rapid budgetary fluctuations can threaten that condition. Part of the difficulty in this budget cycle is that NASA's advisory bodies have been in some disarray. If the science priorities are to be determined wisely, consultation with the appropriate scientific communities is essential. Otherwise, budget proposals, such as this one, run the risk of touching off efforts to save troubled programs outside the normal, proven planning channels, thereby eliminating one of the primary benefits of a priority-setting decadal review.

In summary, I believe that the 2007 NASA budget proposal will not provide the Nation with a healthy and productive astronomy

program. It reduces funding in astronomical sciences by 20 percent over the five-year runout. It damages programs that are necessary to sustain a healthy research community, and it is skewed too heavily toward the large missions. In the current budget climate, NASA might be unable to keep the program as healthy as we would wish. If so, the Agency must consult with the community to find the best solutions.

Thank you very much for your attention.

[The prepared statement of Dr. Taylor follows:]

PREPARED STATEMENT OF JOSEPH H. TAYLOR, JR.

Mr. Chairman, Ranking Minority Member, and Members of the Committee: thank you for inviting me to testify. My name is Joseph Taylor and I am the James S. McDonnell Distinguished University Professor of Physics and former Dean of the Faculty at Princeton University. I served in 1998–2000 as Co-Chair of the National Academies Astronomy and Astrophysics Survey Committee, but my comments today represent my own opinions, informed by discussions with many colleagues in the U.S. astronomy community.

As you know, the astronomy community has a long history of creating, through the National Research Council (NRC), broad surveys of the field at ten-year intervals. These surveys lay out the community's research goals for the next decade; they identify key scientific questions that are ripe for answering, and they propose new initiatives that will make those goals achievable. The most recent decadal survey, entitled *Astronomy and Astrophysics in the New Millennium,* was released in the year 2000.[1] I have been asked to answer the following questions from my perspective as the Co-Chair of the committee that produced that report:

1. What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?
2. Do you believe the decisions NASA has made concerning which missions to defer or cancel are consistent with the most recent National Academies Decadal Survey that you released? Have there been any developments since the Decadal Survey that need to be taken into account, and has NASA considered those? Given the FY07 budget request, do you see any need to update the most recent survey or to change the process for the next Decadal Survey?
3. How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY07 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?

In the balance of my testimony I shall address all three questions.

In previous decades the NRC decadal survey was an activity unique to the astrophysical sciences. The most recent survey involved the direct participation of 124 astronomers as committee and panel members; moreover, these people received input from many hundreds more of their colleagues. Altogether, a substantial fraction of the Nation's astronomers were in some way involved in the creation of the report. By gathering such broad community input, the survey process creates a document that reflects the consensus opinion of the active researchers in the field. The value of this advice to NASA and the National Science Foundation has been demonstrated in many ways. It clearly helped to motivate NASA's requests for the NRC to conduct similar surveys for planetary science,[2] solar and space physics,[3] and Earth science.[4]

The feature of a decadal survey that distinguishes it from summaries of other fields of science is the prioritized list of recommended initiatives. This list is a valuable tool for strategic planning, and it receives considerable attention. As with the use of any tool, some judgment is required in its application. Science priorities drive the assigned priorities of the projects. The science priorities are based on the output

[1] *Astronomy and Astrophysics in the New Millennium,* NRC, 2001.
[2] *New Frontiers in the Solar System,* NRC, 2003.
[3] *The Sun to the Earth—and Beyond,* NRC, 2003.
[4] Study underway—*http://qp.nas.edu/decadalsurvey*

of the research community throughout the country, including its probable extrapolation into the future. The most serious impact of the President's FY 2007 budget proposal is that it threatens to significantly decrease this output by cutting the research and analysis grants lines by 15 percent. At a time when the administration has proposed an American Competitiveness Initiative and many Members of Congress have expressed strong support for increasing research in the physical sciences, this reduction seems counter-productive at best. For the past decade NASA has provided a majority of the Nation's research support in astronomy and astrophysics. The proposed reductions are therefore of considerable concern to the astronomy community.

The damage caused by these budget cuts is compounded by the fact that their impact will be disproportionately felt by the younger members of the community—the assistant professors, post-doctoral trainees, and graduate students. Without research support to pay for their time, this group will be forced to turn to other fields. Many will leave the sciences altogether, and other bright young people will decide not to enter. In a similar vein, severe reductions in the flight rate of NASA's Explorer line of smaller, lower cost missions will be damaging to the field and particularly its ability to attract and retain younger talent. The Explorer satellites have been extremely cost effective and have often been an entry point for younger researchers into mission development and project management. The scientists and engineers who will build and use tomorrow's Great Observatories are building today's Explorers. It would be a tragedy to drive these people away from space science.

It is easy to identify specific impacts of these cuts and others in the budget proposal, but I wish to call attention to a broader impact that addresses your question about the field's ability to retain scientists and engineers. The administration is proposing to reduce near-term opportunities in order to fully fund large, long-term missions. At the same time it is terminating a long-planned, nearly completed facility called SOFIA and indefinitely deferring an entire program called "Beyond Einstein." I believe that the field of astronomy can sustain itself through lean budgetary times if there is opportunity on the horizon, but this budget proposal sends the message that even nearly completed missions may never be flown. It does not provide the positive view of the future that will keep members of the community engaged and attract bright young people to the field.

The primary goal of the year 2000 Decadal Survey was to provide a vision for a sustainable national effort in astronomy and astrophysics—one that would build on the enviable position of leadership in astronomy that America has developed over the past half century and more. I do not believe that the FY 2007 budget submission is consistent with this vision. I believe that NASA is trying to follow the survey recommendations, and I appreciate that it has protected the highest priority mission, the James Webb Space Telescope, and the crown jewel of the space astronomy missions, the Hubble Space Telescope, in the face of significant cost increases. However, as I mentioned when I appeared before you last year to discuss the Hubble Space Telescope, I do not believe that the highest priority missions should be implemented without regard to cost or impact on the overall program. The Decadal Survey recommended that NASA have a mission portfolio with a mix of large, moderate, and small missions. The FY 2007 budget proposal is weighted to an unhealthy extent towards the large missions. The Decadal Survey recommended that NASA maintain adequate funding in research and analysis grants to "ensure the future vitality of the field." I believe that the proposed reduction in the grants line is not consistent with this recommendation.

One very significant scientific development has taken place since the Decadal Survey was released. Confirmation of the universe's accelerating rate of expansion and the existence of some form of "dark energy" have stimulated new research efforts across astronomy, astrophysics, and fundamental particle physics. The NRC's 2003 report *Connecting Quarks with the Cosmos* puts these discoveries into the broader context of understanding the universe and the physical laws that govern it. NASA worked with the community to develop its Beyond Einstein plan, synthesizing the recommendations of the Decadal Survey and the 2003 report into a widely praised strategy for investment in high energy astrophysics. NASA also participated in an interagency process headed by the Office of Science and Technology Policy which produced a detailed plan for NASA, the NSF, and the Department of Energy to move forward in this area. The NSF and DOE are implementing many of these recommendations by increasing research support and planning investments in new instruments and missions, but NASA continues to push the Beyond Einstein program into the indefinite future.

National priorities outlined in the FY 2007 budget submission present NASA and the astronomy and astrophysics community with significant challenges. I do not believe, however, that a new decadal survey is needed immediately. The study we

completed a little over five years ago produced a positive and forward looking document that tried to capture the scientific opportunities ahead of us. Of course science has progressed in the intervening five years, but the priorities we set still look about right. Conducting a new survey at this time would set an unfortunate precedent and encourage undesirable second-guessing at any time in the future. With these things said, it is also clear that some sort of advice from the community is needed now. In the 2005 *NASA Authorization Act,* Congress requested that the NRC provide NASA with a mid-decade performance assessment for each of its scientific programs. The NRC and NASA have agreed to begin this process with the astronomy and astrophysics program, and the NRC is working now to assemble a review panel. One of the goals of this study will be to provide a feasible implementation plan for the rest of this decade. Such a plan should form a solid foundation on which to conduct the next decadal survey at its normal time, near the end of this decade.

One of the keys to crafting a feasible program is to acquire accurate information on the resources necessary to complete each mission. We attempted to gather such information in carrying out the 2000 Decadal Survey, but in retrospect it is clear that our efforts were inadequate. I believe that the correct procedure is for NASA to set up a task force to work with centers and contractors to improve the reliability of the cost, schedule and technology risk estimates, including proper contingencies, for each of the selected missions. Serious departures from these projections in the future should be grounds for consideration of mission cancellation, even for large missions of high priority.

In addition to these specific proposals, I believe it is essential that NASA work harder to communicate with its scientific community—the community that has contributed so much to the Agency's successes over the years. Part of the difficulty in this particular budget cycle is that NASA's advisory bodies have been in disarray, leading to a perceived lack of community input into the Agency's decision-making process. I do not believe there is a foolproof formula for setting priorities across different scientific disciplines, but it is clear that each of NASA's science disciplines must remain independently healthy. Rapid budgetary fluctuations can threaten that condition. I am confident that if the priority-setting process is done well it must include dialogue and consultation with representatives of the appropriate scientific communities. Without such discussion, budget proposals such as this one run the risk of touching off efforts outside the normal, proven planning channels to save troubled programs. This situation would eliminate one of the primary strengths of the decadal survey process: priorities based on the informed consensus of a highly competitive but ultimately cooperative scientific community.

To summarize, I believe that the FY 2007 NASA budget proposal does not present a program that can provide the Nation with a healthy and productive astronomy and astrophysics program. The budget proposal reduces astronomy and astrophysics at NASA by 20 percent over the five-year runout, before inflation is taken into consideration. The proposal damages programs that are necessary for the sustainability of a healthy research community, and it is skewed too heavily towards large missions. It may be that in the current budget climate, NASA is unable to provide the necessary resources to keep the program healthy. If so, NASA must do a better job of working with the community in order to find the best solutions to the challenges that lie ahead.

Thank you for your attention, and I will be pleased to answer questions.

BIOGRAPHY FOR JOSEPH H. TAYLOR, JR.

Born: March 29, 1941, Philadelphia

Married to: Marietta Bisson Taylor; four children

Educational Background:

1963 Haverford College, B.A. (Physics, with Honors)

1968 Harvard University, Ph.D. (Astronomy)

Professional Employment:

1968–69 Harvard University, Research Fellow & Lecturer

1969–72 University of Massachusetts, Assistant Professor

1972–76 Massachusetts General Hospital, Consultant in Mathematics-Neurosurgery

1976 Commonwealth Scientific and Industrial Research Organization, Visiting Scientist
1973–77 University of Massachusetts, Associate Professor
1977–81 Five College Radio Astronomy Observatory, Associate Director
1977–81 University of Massachusetts, Professor of Astronomy
1980–82 Princeton University, Professor of Physics
1982–86 Princeton University, Eugene Higgins Professor of Physics
1984 Institute for Advanced Study, Visiting Professor
1984 Harvard University, Morris Loeb Lecturer on Physics
1986– Princeton University, James S. McDonnell Distinguished University Professor of Physics
1987 Arecibo Observatory, Visiting Scientist
1991 Australia Telescope National Facility, Visiting Scientist
1997–2003 Princeton University, Dean of the Faculty

Research Specialization: Radio Astronomy, Pulsars, Experimental Gravitation

Fellowships:

1963–64 Woodrow Wilson Fellow
1964–68 National Science Foundation Graduate Fellowship

Honors and Awards:

1975 Bart J. Bok Prize, Harvard College Observatory
1980 George Darwin Lecturer, Royal Astronomical Society
1980 Dannie Heineman Prize, American Astronomical Society and American Institute of Physics
1980 Chancellor's Medal, University of Massachusetts
1981 Member, National Academy of Sciences
1981–86 MacArthur Foundation Prize Fellow
1982 Fellow, American Academy of Arts and Sciences
1985 Henry Draper Medal, National Academy of Sciences
1985 D.Sc. (Honorary), University of Chicago
1986 Fellow, American Physical Society
1987 Tomalla Foundation Prize in Gravitation and Cosmology
1990 The Magellanic Premium, American Philosophical Society
1991 John J. Carty Award for the Advancement of Science, National Academy of Sciences
1991 Einstein Prize Laureate, Albert Einstein Society, Bern
1992 Wolf Prize in Physics
1992 Member, American Philosophical Society
1993 Nobel Prize in Physics
1994 D.Sc. (Honorary), University of Massachusetts
1995 Docteur (Honoris Causa), Universite de Montreal
1995 John Scott Medal, City of Philadelphia
1997 Karl Schwarzschild Medal, Astronomische Gessellschaft

Professional Societies:

American Astronomical Society
American Physical Society
International Scientific Radio Union
International Astronomical Union

Professional Activities:

1970–79 Users Committee, National Radio Astronomy Observatory
1976–78 Councilor, High Energy Astrophysics Division, American Astronomical Society

1976–77 Radio Astronomy Panel, Astronomy Survey Committee, National Academy of Sciences
1980–83 Visiting Committee, National Radio Astronomy Observatory
1980–83 Visiting Committee, Kitt Peak National Observatory and Cerro Tololo Inter-American Observatory
1980–83 Astronomy Advisory Committee, National Science Foundation
1980–84 Advisory Board and Visiting Committee, Arecibo Observatory
1985–86 Vice-Chairman, Astrophysics Division, American Physical Society
1986–87 Chairman, Astrophysics Division, American Physical Society
1985–88 Councilor, American Astronomical Society
1986–94 Board of Managers, Haverford College
1987– Board of Trustees, Associated Universities Incorporated
1989–90 Radio Astronomy Panel, Astronomy Survey Committee, National Academy of Sciences
1989–93 Green Bank Telescope Advisory Committee
1990–93 Board of Trustees, Princeton Friends School
1990–91 Chairman, Astronomy Advisory Committee, National Science Foundation
1993–95 National Research Council, Task Group on Gravity Probe B, Co-Chair
1996 NASA Gravitational/Relativistic Physics Review Panel, Chair
1997–2004 Board on Physics and Astronomy, National Research Council
1997–98 Committee on Gravitational Physics, National Research Council
1998–2001 Decade Survey of Astronomy and Astrophysics, National Research Council, Co-Chair
1999–2003 Alan T. Waterman Award Committee, National Science Foundation
2003 Committee on Setting Priorities for the Large Research Facility Projects Supported by the National Science Foundation, National Research Council
2004 Committee on Assessment of Options for Extending the Life of the Hubble Space Telescope, National Research Council

Publications: approximately 200 articles in the professional research literature of physics and astronomy.

Chairman BOEHLERT. Thank you very much, Dr. Taylor.

Dr. Bagenal.

STATEMENT OF DR. FRAN BAGENAL, MEMBER, NATIONAL ACADEMY OF SCIENCES DECADAL SURVEY FOR SUN-EARTH CONNECTIONS; PROFESSOR, ASTROPHYSICAL AND PLANETARY SCIENCES, LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS, UNIVERSITY OF COLORADO

Dr. BAGENAL. Mr. Chairman, Members of the Committee, thank you for the opportunity to speak today.

First let me tell you something exciting that is happening right now. As I speak, engineers are sending commands to New Horizons spacecraft to switch on an instrument, and we will see if it works as well in space as it did on the ground. So last month, the New Horizons spacecraft was launched on its way to Pluto for a 9-year journey to Pluto, and attached to the spacecraft is an instrument here, the student dust counter, which will measure the amount of dust between the Earth and Pluto.

And particularly exciting for me is the fact that this instrument was built by students at the University of Colorado. Most of these students have already been snatched up by the aerospace industry. Over the next decade, something like 60 college students spanning three generations of students will be involved. And with CU being on—one of the top astronaut universities, it is not too far-fetched to imagine that one of these students may end up walking on Mars.

So the cost to NASA of the student dust counter: $1 million of education and public outreach funding. Value of inspiring thousands of students to study math and science: priceless. This is precisely the kind of project that is jeopardized under the new budget: smaller science-led missions and education and public outreach. It makes little sense to attack what is both popular with the public and working well. It is—particularly doesn't make sense to cut the smallest and most productive stuff.

Your Committee asked me to comment on the most serious impacts of the fiscal year 2007 budget. This is dramatically illustrated by the list of science launches for the next seven years. In the next couple of years, there is an impressive list of science missions that will be launched. But this is followed by a precipitous drop to only one launch in 2010 and a few beyond that.

The net result is that there is a significant gap, during which it is inevitable that expertise will be lost, and it will be hard to attract and train junior scientists and engineers, the very people who will be needed to implement the *Vision for Space Exploration.*

How bad do the delays and cutbacks have to be to be called severe? To be honest, I am scared of showing the charts in my written statement that basically says that NASA is going out of business. This 2010 launch gap is in all of the science missions.

For heliophysics, I would like to highlight two supporting programs that are badly hit.

Number one is the Explorer program, a program that many others have mentioned, that elicits many highly-innovative proposals from the community. These small missions were launched at a rate of about one per year and produced great science. The Explorer program has taken dramatic cuts in the last few budget cycles, resulting in the cancellation of the NuSTAR mission and a gap from 2008 to at least 2014 without any Explorer launches. This is a program that is vital to both heliophysics and to astrophysics.

Number two is research and analysis programs, which, again, others have mentioned here. When it comes to sheer science productivity, these small, usually 3-year grants, deliver the most bang for the buck. They are highly competitive, with only a few of the very best ideas: 10 to 20 percent of the very best are selected by a very vigorous peer review. It is something that I think NASA should be very proud of. Any cutbacks to research and analysis acutely impacts the most vulnerable and productive sector of space science.

NASA's administration has suggested that the 2010 mission gap justifies an immediate 15-percent cut in research and analysis across the Science Mission Directorate. The high launch rate in 2006, the many ongoing productive missions, and the Nation's need for a technically-trained workforce all argue that research and analysis programs should be increased, rather than cut.

The scientific priorities set out in the solar and space physics Decadal Survey remain valid today. And I see no community movement to change them. But to design a coherent program across a decade, it is essential to have a realistic budget profile that does not fluctuate violently from year to year, and we need accurate estimates of mission costs. And the costing of just a few missions, the big digs in space, wreck havoc with even the best plans.

Each of NASA's scientific themes makes breakthrough discoveries that hit the headlines. Rather than distinguish between them, I would argue that budget priorities should be made and then kept within each division.

Investments in science have paid off for NASA. I urge Congress to invest in the future and support NASA's small missions and research programs.

Thank you for your attention.

[The prepared statement of Dr. Bagenal follows:]

PREPARED STATEMENT OF FRAN BAGENAL

Good morning, Mr. Chairman and Members of the Committee. My name is Fran Bagenal and I am a professor at the University of Colorado. I served on the committee for the NRC decadal survey for solar and space physics and chaired a committee that assessed the role of solar and space physics in space exploration.

I am here today to provide an evaluation of the impact of the NASA's FY07 budget on solar and space physics—a field of research that corresponds to what is labeled, as of last week, the Heliophysics Division of NASA's Science Mission Directorate. Heliophysics has previously been called Sun-Earth Connections (SEC) and, until last week, sat with Earth Science within Earth-Sun Systems. This evaluation yields six conclusions that are summarized as follows:

1. NASA's investment in science has had a high payoff; it has spurred advances in leading edge technologies and has been instrumental in educating the next generation of scientists.
2. The claimed increase in science's share of the NASA budget is not reflected in science activity and in part arises from a change in accounting rules.
3. There will be a precipitous drop in launches of science missions beginning in 2010 and continuing forward.
4. The Explorer program is experiencing dramatic cuts and set-backs.
5. The Sounding Rocket Program, which serves our nation as a space academy, is withering after more than a decade of flat funding.
6. The FY07 budget makes major cuts in the Research and Analysis Program, which will affect disproportionately the youngest space scientists, and place the health of the space science "workforce" at risk.

To understand these conclusions I would like to begin by giving some context for this area of science.

Heliophysics

The Sun is the source of energy for life on Earth and is the strongest modulator of the human physical environment. In fact, the Sun's influence extends throughout the solar system, both through photons, which provide heat, light, and ionization, and through the continuous outflow of a magnetized, supersonic ionized gas known as the solar wind. The realm of the solar wind, which includes the entire solar system, is called the heliosphere. In the broadest sense, the heliosphere is a vast interconnected system of fast-moving structures, streams, and shock waves that encounter a great variety of planetary and small-body surfaces, atmospheres, and magnetic fields. Somewhere far beyond the orbit of Pluto, the solar wind is finally stopped by its interaction with the interstellar medium.

Thus, interplanetary space is far from empty—an often gusty solar wind flows from the Sun through interplanetary space. Bursts of energetic particles arise from acceleration processes at or near the Sun and race through this wind, traveling through interplanetary space, impacting planetary environments. It is these fast solar particles, together with galactic cosmic rays, that pose a threat to exploring astronauts. The magnetic fields of planets provide some protection from these high energy particles, but the protection is limited and variable, and outside of the planetary magnetospheres there is no protection at all. Thus, all objects in space—spacecraft, instrumentation and humans—are exposed to potentially hazardous penetrating radiation, both photons (e.g., x-rays) and particles (e.g., protons, heavy ions and electrons). Just as changing atmospheric conditions on Earth lead to weather that affects human activities on the ground, the changing conditions in the solar atmosphere lead to variations in the space environment—space weather—that affects activities in space.

Decadal Survey & Vision for Space Exploration

In 2002, the National Research Council published the first decadal strategy for solar and space physics: *The Sun to the Earth—and Beyond: A Decadal Strategy for Solar and Space Physics.*[1] The report included a recommended suite of NASA missions that were ordered by priority, presented in an appropriate sequence, and selected to fit within the expected resource profile for the next decade, which was anticipated to increase substantially through ~FY08.

In early 2004,[2] NASA proposed to adopt major new goals for human and robotic exploration of the solar system, consistent with the Bush Administration's *Vision for Space Exploration.* Any exploration will depend, in part, on developing the capability to predict the space environment experienced by exploring spacecraft and humans. Also in 2004, the Space Studies Board of the National Research Council tasked a committee to assess the role of solar and space physics in NASA's Exploration Vision.[3] This committee stated that:

> NASA's Sun-Earth Connection program depends upon a balanced portfolio of space flight missions and of supporting programs and infrastructure, which is very much like the proverbial three-legged stool. There are two strategic mission lines—Living With a Star (LWS) and Solar Terrestrial Probes (STP)—and a coordinated set of supporting programs. LWS missions focus on observing the solar activity, from short-term dynamics to long-term evolution, that can affect the Earth, as well as astronauts working and living in near-Earth space environment. Solar Terrestrial Probes are focused on exploring the fundamental physical processes of plasma interactions in the solar system. A key assumption upon which the LWS program was designed was that the STP program would be in place to provide the basic research foundation from which the LWS program could draw to meet its more operationally oriented objectives. Neither set of missions can properly support the objectives of the Exploration Initiative alone. Furthermore, neither set of space flight missions can succeed without the third leg of the stool. That leg provides the means to (a) conduct regular small Explorer missions that can react quickly to new scientific issues, foster innovation, and accept higher technical risk; (b) operate active spacecraft and analyze the LWS and STP mission data; and (c) conduct ground-based and sub-orbital research and technology development in direct support of ongoing and future space flight missions.

I will return to this issue of balance between these three legs of basic, applied and supporting research later in my testimony.

This re-evaluation of the Decadal Survey endorsed the original scientific and mission priorities—emphasizing a balance in the fundamental and applied aspects of space physics—but recognized that the schedule of missions would have to be considerably stretched out to fit a leaner budget.

Science Mission Directorate FY07 Budget

With this background, let me proceed to NASA's FY07 budget. First, may I commend Administrator Dr. Griffin's bold leadership of NASA and his clear command of the technical issues involved. We all recognize the enormous challenge of enacting the *Vision for Space Exploration* while fulfilling international obligations associated with Space Station. NASA is being asked to do Apollo with a post-Apollo budget. Yet we must also remember that science is a vital part of the *Vision for Space Exploration.* I repeat the refrain "Exploration without science is just tourism."

In his February 16th statement to this committee, Dr. Griffin quoted that fraction of the NASA budget allocated to science had grown from 24 percent to 32 percent between 1992 and 2007. These figures were emphasized in his oral presentation with the explicit implication that this fraction should be reduced by having the science budget slow down to a one percent growth rate while NASA as a whole grows three times faster. First of all, I do not claim to know what fraction of the NASA budget is the "correct" value to be spent on science. But I submit that the dramatic close-up views of our Sun from SOHO and Trace as well as the exciting new worlds revealed by Voyager, Hubble, Mars rovers, and Cassini have permanently changed the American people's view of space science. *Investment in science*

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[1] National Research Council, *The Sun to the Earth—and Beyond: A Decadal Strategy for Solar and Space Physics,* The National Academies Press, 2002.

[2] National Aeronautics and Space Administration, *The Vision for Space Exploration,* NP–2004–01–334–HQ, NASA, Washington, D.C., 2004.

[3] National Research Council, *Solar and Space Physics and Its Role in Space Exploration,* The National Academies Press, 2004.

has paid off for NASA—not only in terms of cultural and intellectual benefits but also in enabling technology and inspiring young scientists and engineers.

Secondly, I accept that the science budget has seen net growth—and a third of the NASA's $17 billion budget is a substantial amount to spend on science. The reason for this growth is partly because of demonstrated successes. But I point out that over the past 15 years there have been significant changes in the way NASA has been bookkeeping different components of the budget (e.g., project management & operations, salaries of civil servants, and particularly launch costs which have doubled in the past ~5 years). I suggest that the quoted eight percent increase in the share of the NASA budget being labeled as science does not necessarily reflect a corresponding increase in scientific activity. It might be useful for your committee to task one its support agencies; for example, the Government Accountability Office, to evaluate of how these budget figures are tracked. At the very least, I caution against taking this simple statistic at face value and using it to rationalize the diminishment of what has been one of NASA's great successes—science.

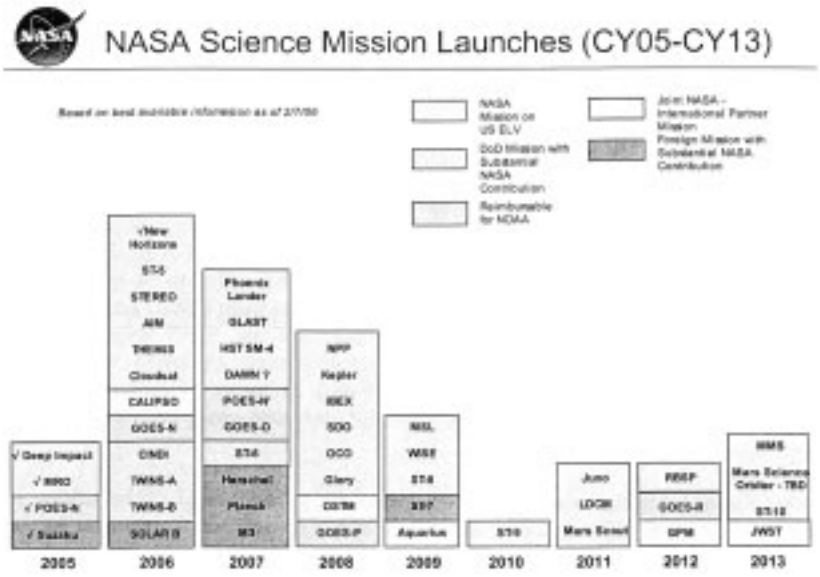
Heliophysics Budget

I have been asked to address the following specific questions:

1. *What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?*

Science Mission Launches

The impact of elimination of growth in SMD is most dramatically illustrated by the following chart of science mission launches for the next seven years. An impressive list of missions to be launched in the next couple of years is followed by a precipitous drop to only one launch in 2010 (ST–9, a small technology demonstration mission) and few launches per year thereafter.



Since each mission takes several years of development and construction before launch (~3 years for small missions, over a decade for the largest missions) this paucity of missions beyond 2010 reflects a slowdown in mission opportunities over the past ~5 years and a lack of launch opportunities for several more years. Factors contributing to this dearth of launches are the escalation in launch costs, the impact of full-cost accounting, the under-costing of larger missions, and—most significantly—the elimination of any funding wedge for new missions from here onwards. *The net result is that there is a significant gap during which it is inevitable that*

expertise will be lost and it will be hard to attract and train junior scientists and engineers—the very people who will be needed to implement the *Vision for Space Exploration. While the lack of any large missions on the horizon is a concern, the priority for Heliophysics must be a steady cadence of smaller missions.*

The Explorer Program

In the past, the Explorer program has offered frequent opportunities to carry out small and medium sized missions that can be developed and launched in a short (approximately four-year) timeframe. The Explorer Program straddles both the Heliophysics and Astrophysics Divisions with roughly equal numbers of launches in each division.

These focused missions address science of crucial importance to these two division roadmaps and NRC Decadal Surveys: The 2004 NRC report "Solar and Space Physics and Its Role in Space Exploration" states that: Explorers *"are the lifeblood of SEC research because they provide core research, flexibility, innovative technologies, and invaluable training for the next generation of workers for our nation's space enterprise. The Explorer program provides innovative, fast-response missions to fill critical gaps."* The report recommends *"these programs should continue at a pace and a level that will ensure that they can fill their vital roles in SEC research."* The 2001 NRC report "Astronomy and Astrophysics in the New Millennium" finds that *"the Explorer program is very successful and has elicited many highly innovative, cost effective proposals for small missions from the community."* Specifically they recommend *"the continuation of a vigorous Explorer program,"* and that *"NASA should continue to encourage the development of a diverse range of mission sizes, including small, moderate, and major, to ensure the most effective returns from the U.S. space program."*

In the last decade, 10 Explorers were launched; six small explorers (SMEX) and four medium explorers (MIDEX). These have allowed NASA to respond quickly to new scientific and technical developments, and have produced transformational science, including:

- The best determination of the age of the universe: 13.7 billion years.
- Images of solar flares that show that ions and electrons are accelerated in different locations.
- The discovery of "baby" galaxies still in the process of forming, long after the vast majority of galaxies formed during the early universe.
- Measurements of record-speed solar winds (at ~5 million mph) from the large "Halloween" 2003 solar eruptions.
- The discovery that the plasmasphere rotates with the Earth at only 85–90 percent of the Earth's rotation rate as opposed to the 100 percent assumed by all models of magnetospheric convection.
- Direct evidence that galactic cosmic rays originate in associations of massive stars (where most supernovae occur).
- Proof that short-duration gamma-ray bursts (lasting less than two seconds) have a different origin than long bursts, likely resulting from the fiery mergers of binary neutron stars.
- These are a small fraction of highlights selected to illustrate the astounding breadth and productivity of the program.

The Explorer program has taken dramatic cuts in the last few budget cycles, resulting in:

- The cancellation—for purely budgetary reasons—of a peer-reviewed, selected mission, the *Nuclear Spectroscopic Telescope Array (NuSTAR)* SMEX, chosen (along with the *Interstellar Boundary Explorer (IBEX)*), from the 2002 announcement that solicited two flight missions.
- Delay in the next Announcement of Opportunity until mid 2008 at the soonest (associated mission launch beyond 2014).

The result is a minimum gap from 2008–2014 without any Explorer launch, in a program that is vital to both Heliophysics and Astrophysics, and which in the past has seen an average of one launch per year.

As noted in numerous NRC reports, in addition to its scientific importance, there are compelling programmatic, technical and educational reasons to maintain a line of small and moderate-sized competed missions. Explorers have strong involvement of the university community (eight of the ten most recent Explorers have been led by university scientists), and they provide an excellent training ground for young experimental researchers, scientists, engineers and managers, many of whom go on

to play lead roles in large missions. The time from development to launch is consistent with Ph.D. degree programs, as well as time scales for the career development of young professional scientists.

This decimation of the Explorer program will have a lasting and significant impact on the Nation's academic research base. Universities and research laboratories make significant internal investments in infrastructure to support experimental space science. Decisions on faculty and staff hires, on accepting graduate students, and the institutional investment in specialized laboratory facilities all depend on existence of a vital research and analysis (R&A) program, and opportunities to develop instrumentation for space flight. Both of these are threatened in the current NASA budget. In particular, the cancellation of missions after they have completed the arduous competitive process and been selected, as happened in the most recent budget process, is a particularly dangerous precedent. Universities, research laboratories, and their international collaborators necessarily rely on the well-established Explorer selection process in their decision to undertake such long-term commitments. *The precedent will be detrimental to the strong partnership between NASA and university researchers, a partnership that has been key to much of NASA's scientific productivity and has provided critical opportunities for developing scientists and engineers in experimental space science.*

Sub-orbital Sounding Rocket Program

Sub-orbital sounding rocket flights and high-altitude scientific balloons can provide a wide range of basic science that is important to meeting Heliophysics program objectives. For example, sounding rocket missions targeted at understanding specific solar phenomena and of the response of the upper atmosphere and ionosphere to those phenomena have potentially strong relevance. This science is cutting-edge, providing some of the highest-resolution measurements ever made and, in many cases, providing measurements that have never been made before.

The Sub-orbital program serves several important roles, including:

- Conducting important scientific measurements in support of orbital space flight missions,
- Providing a mechanism to develop and test new techniques and new space flight instruments, and
- Providing effective training to develop future experimental scientists and engineers.

Development of new scientific techniques, scientific instrumentation, and spacecraft technology is a key component of the Sub-orbital program. Many of the instruments flying today on satellites were first developed on sounding rockets or balloons. The low cost of sounding rocket access to space fosters innovation: instruments and technologies warrant further development before moving to satellite programs. Development of new instruments using the Sub-orbital program provides a cost-effective way of achieving high technical readiness levels with actual space flight heritage.

The fact that any long-term commitment to space exploration will place a concomitant demand on the availability of a highly trained technical work force makes the training role of the Sub-orbital program especially important. For example, a three-year sounding rocket mission at a university provides an excellent research opportunity for a student to carry a project through all of its stages—from conception to hardware design to flight to data analysis and, finally, to the publication of the results. This "hands on" approach provides the student with invaluable experience in understanding the space flight mission as a whole. Indeed, over 350 Ph.D.s have been awarded as part of NASA's sounding rocket program. Not only have some of these scientists have gone on to successfully define, propose, and manage bigger missions such as Explorer, many more have brought valuable technical expertise to private industry and the government workforce.

NASA budgets for the Sub-orbital Sounding Rocket Program have remained flat. When one allows for inflation and the dramatically escalating launch costs, the net effect is a significant reduction in the capabilities of the program. *Given the valuable educational, training and technology development roles of sounding rockets, any small saving derived from limiting this minor program has a major impact on future technical capabilities.*

Research and Analysis Programs

Research and Analysis (R&A, sometimes called Supporting Research and Technology SR&T) programs are crucial for understanding basic physical processes that occur throughout the Sun-heliosphere-planet system, and for providing valuable support to exploration missions. The objectives of R&A programs include:

- Synthesis and understanding of data gathered with spacecraft,
- Development of new instruments,
- Development of theoretical models and simulations, and
- Training of students at both graduate and undergraduate levels.

R&A programs support a wide range of research activities, including basic theory, numerical simulation and modeling, scientific analysis of spacecraft data, development of new instrument concepts and techniques, and laboratory measurements of relevant atomic and plasma parameters, all either as individual projects or, in the case of the SEC Theory program, via "critical mass" groups. Theory and modeling, combined with data analysis, are vital for relating observations to basic physics. Numerical modeling can also be a valuable tool for mission planning. Insights obtained from theory and modeling studies provide a conceptual framework for organizing and understanding measurements and observations, particularly when measurements are sparse and when spatial-temporal ambiguities exist. Theory and modeling will be especially important in the context of the space exploration initiative as exploration missions become more complex and the need for quantitative predictions becomes greater. *These programs also are especially valuable for training students, at both the undergraduate and the graduate level, who will likely play a vital role in the NASA space exploration initiative or join the larger workforce as capable scientists/engineers/managers who cut their teeth on rigorous problems.*

NASA administration has suggested that the 2010 mission gap justifies an immediate 15 percent cut in R&A across the Science Mission Directorate. The high launch rate in 2006, the extensive list of on-going productive missions and the Nation's need for a technically-trained workforce all argue that R&A should be increased rather than cut.

When it comes to shear science productivity, R&A grants deliver the most "bang for the buck." These usually three-year grants of ~$100k/year are highly competitive with only the very best 10–20 percent being selected via rigorous peer review. Even the most established scientists have to compete with everyone else. R&A programs provide the main basis of support for junior scientists—graduate students and postdoctoral researchers. *Any cutbacks to R&A acutely impacts the most vulnerable and productive sector of space science.*

2. *Do you believe the decisions NASA has made concerning which missions to defer or cancel are consistent with the most recent National Academies Decadal Survey that you released? Have there been any developments since the Decadal Survey that need to be taken into account, and has NASA considered those? Given the FY07 budget request, do you see any need to update the most recent survey or to change the process for the next Decadal Survey?*

The 2004 NRC report, *Solar and Space Physics and Its Role in Exploration,* examined the 2002 Decadal Survey made the following three recommendations:

1. *To achieve the goals of the exploration vision there must be a robust SEC program, including both the LWS and the STP mission lines, that studies the heliospheric system as a whole and that incorporates a balance of applied and basic science.*
2. *The programs that underpin the LWS and STP mission lines—MO&DA, Explorers, the suborbital program, and SR&T—should continue at a pace and level that will ensure that they can fill their vital roles in SEC research.*
3. *The near-term priority and sequence of solar, heliospheric, and geospace missions should be maintained as recommended in the decadal survey report both for scientific reasons and for the purposes of the exploration vision.*

These recommendations remain valid today. The mission priorities within the basic science (STP) and applied science (LWS) mission lines as listed in the original Decadal Survey are generally reflected in the Heliophysics budgets for these two mission lines. Where NASA has deviated from the Decadal Survey is in putting greater weight on Living With a Star missions and losing the balance between applied and basic science. Such a priority of emphasizing short-term capability of predicting space weather over the long-term goal of understanding the underlying physical principles may have some practical expedience. A more critical issue, however, is the fact that small missions and supporting research have not kept pace. If these programs—the components that comprise the third leg of the stool and the training grounds for new scientists and engineers—are allowed to wither, Heliophysics will quite quickly topple over.

The 2002 Decadal Survey, *The Sun to the Earth—and Beyond,* was the first conducted by the solar and space physics community (though smaller NRC committees

have generated many shorter planning documents). The Decadal Survey involved hundreds of scientists in discussions that spanned nearly two years. The scientific priorities set out the survey remain valid today and I see no community movement to change them. But Decadal Surveys are not just a list of science priorities. To design a coherent program across a decade, it is essential to have a realistic budget profile as well reasonably accurate estimates of both technical readiness and costs of each mission. The Decadal Survey committee worked hard with engineers and NASA management to develop realistic mission costs and a program architecture that fit within budget profiles anticipated in FY03 budget. But changes to the budget profile in FY04 necessitated a substantial stretching of the mission schedule in the 2004 re-assessment of the Decadal Survey in light of the *Vision for Space Exploration.*[4] Furthermore, under-costing of just a few missions—Big Digs in space—wreck havoc with even the best-laid plans. The scientific community needs to work with NASA to find ways to accurately cost missions, particularly large missions (e.g., by applying lessons learned from management of smaller, PI-led missions as appropriate and greater accountability).

3. *How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY07 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?*

Each of NASA's scientific themes makes breakthrough discoveries that hit the press headlines. Rather than distinguish between them, I would argue that budget priorities be made within each division and, should a project exceeds its budget, any accommodation be made within the division. This would enforce accountability.

NASA conducts an outstanding program of scientific research within its Science Mission Directorate. The market place for scientific ideas—whether for a $100,000/yr research grant or a $1 billion mission—is a highly competitive world where only the very best ideas survive. NASA's science missions excite the public's interest in the universe around them, inspire young students to study math and science, and provide opportunities to generate a technically-trained workforce who contribute to the Nation's economy. Heliophysics not only has cultural and intellectual value but also adds practical and economic value as the Nation embarks on its next wave of space exploration.

BIOGRAPHY FOR FRAN BAGENAL

Dr. Fran Bagenal was born and grew up in England. In 1976, inspired by the Viking mission to Mars and the prospect of the Voyager mission, she came to the U.S. for graduate study at MIT. Her 1981 Ph.D. thesis involved analysis of data from the Voyager Plasma Science experiment in Jupiter's giant magnetosphere. She spent 1982–1987 as a post-doctoral researcher in space physics at Imperial College, London. Voyager flybys of Uranus and Neptune brought her back to the U.S. and she joined the faculty at the University of Colorado, Boulder in 1989. She is Professor of Astrophysical and Planetary Sciences and faculty associate of the Laboratory of Atmospheric and Space Physics.

In addition to the Voyager mission, Dr. Bagenal has been on the science teams of the Galileo mission to Jupiter and the Deep Space 1 mission to Comet Borrelly. She edited *Jupiter: Planet, Satellites and Magnetosphere* (Cambridge University Press, 2004). She heads the plasma teams on the first two New Frontiers missions: New Horizons mission to Pluto (launched January 2006) and Juno, a Jupiter polar orbiter (scheduled for launch 2010/11).

Dr. Bagenal has served on several committees of the National Research Council of the National Academy of Sciences: Space Studies Board, Committee on Planetary and Lunar Exploration, Solar and Space Physics Decadal Survey Committee, and chaired the Committee to Assess the Role of Solar and Space Physics in Exploration. She chairs NASA's Outer Planets Assessment Group.

Dr. Bagenal became a U.S. citizen on 9/6/2001 and Fellow of the American Geophysical Union in 2006.

Chairman BOEHLERT. Thank you very much, Dr. Bagenal.

Dr. Huntress.

[4] See charts on page 26 of *Solar and Space physics and Its Role in Space Exploration,* The National Academies Press, 2004.

STATEMENT OF DR. WESLEY T. HUNTRESS, JR., MEMBER, NATIONAL ACADEMY OF SCIENCES DECADAL SURVEY FOR SOLAR SYSTEM EXPLORATION; DIRECTOR, GEOPHYSICAL LABORATORY, CARNEGIE INSTITUTE OF WASHINGTON

Dr. HUNTRESS. Mr. Chairman and Members of the Committee, I am grateful for the opportunity also to testify before you here today. I have appeared before this committee many times in my career, and that record shows me, I think, to be an advocate for the scientific exploration of space, using both robotic and human elements, with the emphasis on scientific.

Two years ago, the President released his *Vision for Space Exploration* and provided a budget that would support it. In the intervening two years, the Administration has reduced this budget to the point where the plan is insupportable. Last year, aeronautics and technology suffered. This year, the Agency's science program is to be cannibalized, even though the NASA Administrator had promised not to transfer "one thin dime" from scientific exploration into human space flight.

The President's policy is not just about human space flight. The very first goal stated in the Vision is to implement a sustained and affordable human and robotic exploration program to explore the solar system and beyond, and to conduct robotic exploration across the solar system for scientific purposes and to support human exploration. This eye of the Vision seems to have lost its sight.

This Administration's budget proposal loans $3.07 billion from the five-year runout of NASA's science budget to pay for the Shuttle and ISS completion. Of the several disciplines in NASA's science, solar system exploration, alone, is to pay 97 percent of that bill, $2.99 billion, even though robotic exploration of the solar system is one of the most relevant to science enterprises and human exploration.

This simply cannot be done without serious damage to an enterprise in the community that should, and needs to be, a partner with human exploration. Space science has been carrying the Agency exploration flag throughout the 1990s and into this new century, and the Agency has been justly proud of the productivity of these missions. missions such as Hubble, the Mars Exploration Rovers, the Cassini/Huygens mission at Saturn are, as Administrator Griffin, himself, said, the "crown jewels" of NASA, yet he has set NASA science on a declining course, not even keeping up with the projected growth in the rest of the Agency over the next five years.

It simply makes no sense to cut science in NASA when the President told the Nation in the State of the Union address that we must increase our investment in science. Space exploration is an enormous draw to young scientists and engineers, but we are pulling the rug out from under their future.

NASA's science enterprise is not just about flight missions. It is about, and foremost about, science. Flight missions are the tools. The science community and our universities, research organizations, and NASA's Centers are the very foundations of NASA science, and they are the soil out of which NASA's flight missions grow. Yet, the fiscal year 2007 budget will reduce their funding by 15 percent across the board, and for reasons hard to fathom, one program, astrobiology, is targeted for a 50-percent reduction. The

consequences of these reductions would be to cripple the ability of NASA science enterprise that create a generation of new scientists, a new generation of flight missions, and worst of all, it will short-circuit the careers of young scientists, precisely the opposite of what this country needs in order to remain competitive.

All of these cuts are immediate in this fiscal year, dimming the prospects of many young motivated students now. What kind of message is that to the best and brightest of America's hopes for a rich technological future? If there is to be any science at all in human space flight to the Moon and beyond, it needs to come from these very same young people.

The major damage in the budget to solar system flight missions to the Mars and Outer Planets flight programs. Mars flight missions are reduced from a nominal two launches per opportunity to only one, and the number of medium-class missions is reduced. Two small Scout missions are eliminated, and technology developments for missions beyond 2009 are cut.

For the Outer Planets program, the Europa Orbiter mission, the only flagship mission and the highest science priority, is deferred to the next decade. For the first time in four decades there will be no solar system exploration flagship at all, and we will remain ignorant that much longer of Europa's deep ocean and the potential for life within it.

The small and medium-class missions that are the sustaining elements of the planetary flight program are at risk.

The inevitable result of all of these delays and deletions is the potential loss of technological expertise to conduct these missions. It is not possible to retain the best of people if there is a lack of stability and no clear sense of a strong future. You can't have world-class flight missions without world-class people.

The bottom line is that the future of our nation's solar system exploration program has been mortgaged. The momentum of current mission development will probably carry it for about two years, but then the bottom begins to fall out.

In lean times, the most important elements for sustaining the enterprise are: first, the fundamental research the programs that form the basis for solar system exploration; second, technology development to allow for the future of missions of all classes; and third, the lowest cost, highest flight rate, competed flight programs in the small and medium flight mission lines. This budget fails to do all of those things.

The President's Vision is about robots and humans exploring to find our destiny in the solar system together. Instead of drawing on the strengths of both, this budget pits one versus the other, undermining the Vision, rather than promoting. It pawns a planetary exploration program that is the envy of the world. No one else is going to Pluto.

The Administrator's budget message said about the Vision, "We will go as we can afford to pay." But the only way he can pay is by taking resources from the future of science and technology. If these annual reductions in NASA's budget continue, and if NASA continues to drain resources from science and technology, then America can retire as the leading nation in the scientific exploration of space, whether by robots or by humans.

Mr. Chairman, Members of the Committee, thank you very much.

[The prepared statement of Dr. Huntress follows:]

PREPARED STATEMENT OF WESLEY T. HUNTRESS, JR.

Mr. Chairman and Members of the Committee:

I am grateful for the opportunity to testify before you today. I have appeared before this committee many times in my former job as the NASA Associate Administrator for Space Science, and few times since. I now appear before you to address concerns about the future of America's Earth and space science in NASA's proposed FY07 budget.

The top line for NASA

I am an advocate for the scientific exploration of space—using both robotic and human elements—with the emphasis on *scientific* exploration. I also believe in the President's new Space Policy and that the CEV is the right way to start. But this FY07 budget proposes to implement the two-year-old *Vision for Space Exploration* without sufficient funding, and as a consequence does considerable damage to NASA's robotic, scientific exploration program. NASA's plans have been called Apollo on steroids, but the budget provided is Apollo on food stamps.

Two years ago when the President released his Vision, he provided an FY05 budget proposal with new funds in the five-year run out that would support it. In the intervening years, the Administration has reduced this budget to the point where the plan is insupportable. Last year, the Administration cut that budget, forcing the Agency to take the money from aeronautics and technology funding. This year, the Administration has reduced the budget yet again, forcing the Agency to take an even larger chunk of money from the only enterprise left undamaged in the Agency—science.

The White House wants U.S. obligations to the International Space Station partners to be honored, the Space Shuttle flown as many times as necessary to complete the station's construction, and a replacement for the Shuttle (the Crew Exploration Vehicle, or CEV) flying by 2014. The only problem is that these requirements were handed to NASA without the $3 billion to $5 billion necessary for flying the required number of Shuttle flights to complete space station construction. This forced the NASA administrator to cannibalize the Agency's science program even though he promised last year not to transfer "one thin dime" from scientific exploration into human space flight.

The President's Space Policy is not just about human space flight. The very first goal stated in the Vision is to "implement a sustained and affordable human and robotic program to explore the solar system and beyond." The Vision further advocates that we "conduct robotic exploration across the solar system for scientific purposes and to support human exploration." This eye of the Vision seems to have lost its sight.

The top line for NASA Science

The Administration's 2007 budget proposal removes $3.07 billion from the previously planned five-year run out of the Earth and space science budget. Of this, $2.99 billion is to come from solar system exploration alone. Of the several disciplines in Earth and space science, solar system exploration alone is to pay 97 percent of the bill for the Shuttle even though robotic exploration of the solar system is one of the most relevant of science enterprises to human exploration.

This simply cannot be done without serious damage to an enterprise and community that should, and needs to be, a partner with human exploration.

NASA officials attempt to put positive spin on this damage by citing the growth of space science in NASA from about 21 percent of the budget in 1992 to 32 percent today. But, during that same time period space science has been carrying the Agency exploration flag, and the Agency has been rightly proud of the productivity of the Earth and space sciences. Missions such as Hubble, Mars Exploration Rovers and Cassini/Huygens are, as Administrator Griffin himself said, the "crown jewels" of NASA. Yet he has set NASA science on a declining course, not even keeping up with the projected growth in the rest of the Agency over the next five years.

Does it make good business sense to damage the most productive enterprise in your portfolio to promote a poorly performing one that you firmly expect to terminate in five years?

The President wants to grow federal investment in science

And does it make sense to cut science in NASA when the President told the Nation in his State of the Union address that we must increase our investment in science to insure that America retains its competitive edge? The Senate has taken action on this issue with the "Preserving America's Competitive Edge" Acts (PACE Acts). But the NASA budget ignores both the President's directive and language in S.R. 2198 authorizing 10 percent increases in NASA basic research through 2013. Congress should correct this oversight as the House moves to bills similar to the Senate's PACE Acts.

The President's arguments on the need to increase federal support of the physical sciences are particularly true of NASA science. Space exploration is an enormous draw to young people. This nation never saw such an increase in new science graduates than after the start of the Space Age in 1957. Now, at the start of the President's new *Vision for Space Exploration,* we are doing everything we can to turn off brilliant young Earth and space scientists by pulling the rug out from their prospects for the future.

The FY07 budget proposal and the NRC's Solar System Decadal Report

The FY07 budget proposal does serious damage to the course set for the Nation's solar system exploration enterprise in the NRC's Solar System Decadal Report through its recommendations for research, technology and flight missions. This National Academy report establishes the scientific goals for robotic solar system exploration for the decade 2003–2012, the measurements at solar system destinations required to meet those science goals, and the flight missions necessary to travel to these destinations. The report also makes recommendations on the basic research and technology developments required to support those flight missions and to prepare for future missions beyond the next decade.

Depleting the Science Pool

NASA's Earth and space science enterprise is not just about flight missions. It is foremost about science. Flight missions are the tools for conducting that science—for implementing scientific exploration of our solar system and beyond. Science flight missions are not furnished by the government to the science community, they are created by the science community. Scientists constantly generate new science questions from their research and from previous mission results. They then devise the measurements that need to be made in order to answer those questions. And finally they work with the engineers to create flight mission concepts to make those measurements at solar system destinations. These scientists are spread throughout the country, conducting their basic research in universities, research centers and NASA Centers. They are supported primarily by NASA research grants in what's known as Research and Analysis programs, or R&A, and by grants for mission data analysis also now covered in the R&A portion of the SMD budget.

While the 2003 Solar System Decadal Report recommends that R&A be increased over this decade at a rate above inflation, the FY07 budget would reduce funding for R&A by 15 percent across the board. For reasons hard to fathom, one particular program, Astrobiology, is targeted for a 50 percent reduction. Astrobiology was specifically named by the Decadal report as an important new component in the R&A program and is recognized even outside NASA as the Agency's newest and most innovative research program bringing biologists, geologists and space scientists together to understand the earliest life on Earth and how we might search for life elsewhere beyond our own planet.

The consequences of these unprecedented reductions would be to cripple the ability of NASA's science enterprise to create the next generation flight missions and worse of all it will short-circuit the careers of many young scientists. Precisely the opposite of what this country needs to remain competitive.

And all these cuts are immediate—today, in the 2006 budget year. Grants are to be reduced immediately, dimming the prospects of many young, motivated students now. What kind of message is that to the best and brightest of American's hopes for a rich technological future? And if there is to be any science at all in human space flight to the Moon and beyond, it needs to come from these young people.

Reducing Flight Missions

The Decadal Report also prioritizes the flight missions proposed for the next decade within separate cost categories—small, medium and large.

For small missions, the report assumes a Discovery program of low cost, competed missions at a rate of about one launch per 18 months or about six per decade, and for the Discovery-like Mars Scouts about three launches per decade. Both of these assumptions are based on their historical annual budget levels.

For medium-class missions, the report assumes a New Frontiers program of competed missions at a rate of about three per decade. This is the rate established for the New Frontiers line when it was opened with the Pluto/Kuiper Belt mission.

For large, flagship missions, the report assumes one per decade based on historical data for new starts in this category (Viking in the 1970s, Galileo in the 1980s, and Cassini-Huygens in the 1990s).

For the Mars Exploration flight program, the Decadal report assumed approximately two launches every 26 months, either two medium-class launches or one medium and one small Mars Scout mission depending on timing and cost for the specific missions. This was based on the annual funding level for Mars Exploration in 2003.

The major damage in the FY07 budget to solar system flight missions is to the Mars and the Outer Planets flight programs. Mars flight missions are reduced from a nominal two launches per opportunity to only one, and the number of medium missions is reduced by alternating launch opportunities between medium and small. Two Mars Scouts are eliminated, technology developments for missions beyond 2009 are reduced, and developments for a potential Mars Sample Return mission in the next decade practically eliminated. All of this will hobble our search for signs of past water and perhaps early life on our next-door neighbor.

For the Outer Planets flight program, the Europa Orbiter mission, only flagship mission and the highest science priority, is deferred to the next decade. For the first time in four decades there will be no solar system flagship mission at all. For science, we will remain ignorant that much longer of Europa's deep ocean and the potential for life within it.

The Discovery program of small missions is already in prolonged delay and there will be no launch until the end of the decade, for a hiatus of more than four years since the last. And the third New Frontiers mission selection is delayed by about a year.

The inevitable result of these delays and deletions is the potential loss of technological expertise to conduct these missions. Young scientists and engineers will be forced to look elsewhere for a more reliable, sustainable career path. It is not possible to retain the best of people if there is a lack of stability and a no clear sense of a strong future. You can't have world-class flight missions without world-class people.

Tossing Technology

For this reason, more than the flight mission delays themselves, a failure to continue to develop the technologies required for accomplishing future missions short circuits the future. Sustaining funding for technology development is the key to surviving hard times in flight mission development and guaranteeing a future. This budget does just the opposite.

Concern for the future

The bottom line is that the future of our nation's solar system exploration enterprise has been mortgaged. The momentum of current mission development will carry it for about two years, and then the bottom begins to fall. We must sustain the science and technology that will afford us a new future when we get there two years from now.

Consistent with the NRC Decadal study, the most important elements to sustain the enterprise are the fundamental research programs that form the basis for solar system exploration and the lowest cost, highest flight rate, widely competed flight programs in the small to medium flight mission lines. And if we are ever to recover, we must also invest in our technological readiness for flagship missions in the future.

Is this the best Vision?

The Vision is about robots and humans exploring to find our destiny in the solar system together. Instead of drawing on the strengths of both, this budget pits one vs. the other and undermines the Vision rather than promoting it. It pawns a planetary exploration program that is the envy of the world to pay for a program beset with problems and slated for termination.

The Administrator's budget message said about the Vision, "we will go as we can afford to pay." But the only way he can pay is by taking resources from the future of science and robotic exploration. If these annual reductions in NASA's budget continue, and if NASA continues to drain resources from science and technology, then America can retire as the leading nation in the scientific exploration of space, whether by robots or by humans.

BIOGRAPHY FOR WESLEY T. HUNTRESS, JR.

Dr. Wesley T. Huntress, Jr., is Director of the Geophysical Laboratory of the Carnegie Institute of Washington. Dr. Huntress joined the Carnegie staff in September 1998 after a 30-year career as a scientist and administrator in the Nation's space program. At the Geophysical Laboratory he directs one of the Nation's most prestigious scientific establishments in the geosciences. Dr. Huntress continues his research at GL in astrochemistry and remains a community leader in the scientific exploration of the solar system.

Dr. Huntress earned his Bachelor of Science degree in chemistry from Brown University in 1964 and his Ph.D. in Chemical Physics from Stanford University in 1968, after which he joined the science staff at Caltech's Jet Propulsion Laboratory. Dr. Huntress left JPL in 1988 to join NASA Headquarters in Washington, DC, where he served the Nation's space program for ten years. From 1988 to 1990 he was assistant to the Director of the Earth Sciences and Applications Division, from 1990 to 1992 he was Director of the Solar System Exploration Division and from 1993 to 1998 he served as NASA Associate Administrator for Space Science.

At JPL, Dr. Huntress participated in several missions, as a co-investigator on the Giotto Halley Comet mission, coma scientist for the Comet Rendezvous Asteroid Flyby mission, and as pre-project study scientist for the Cassini mission. He also served in a number of line and program management assignments at JPL. Dr. Huntress and his research group at JPL gained international recognition for their pioneering studies of chemical evolution in interstellar clouds, comets, and planetary atmospheres. Dr. Huntress's last year at JPL in 1987–1988 was spent as a Visiting Professor of Cosmochemistry in the Department of Planetary Science and Geophysics at Caltech. In 1999 the Director of JPL appointed Dr. Huntress to the position of Distinguished Visiting Scientist at JPL.

As Associate Administrator for Space Science at NASA Headquarters, Dr. Huntress was a key architect of the "smaller, faster, cheaper" mission model, and opened up new opportunities for space scientists and industry through new and innovative methods for carrying out Space Science missions. Dr. Huntress created a new, scientifically integrated Space Science program with a clear strategic vision for the future and a new strong emphasis on technology development. In carrying out this strategy, Dr. Huntress is responsible for starting a number of new missions lines including the New Millennium technology flight test program, a restructured Explorer program, the Discovery program of low-cost planetary missions including the Near-Earth Asteroid Rendezvous and Mars Pathfinder missions, the ongoing Mars Exploration Program, and Solar-Terrestrial probes series. Dr. Huntress is also the architect of NASA's new Origins program featuring new technology development in spacecraft and science instrument technologies and approvals for new space science missions such as the Next Generation Space Telescope, the Space Interferometer Mission and the future Planet Finder. Dr. Huntress is the founder of NASA's Astrobiology program.

Dr. Huntress is the recipient of many NASA awards including the NASA Exceptional Service Medal in 1988, the NASA Outstanding Leadership Medal in 1994, the NASA Distinguished Service Medal in 1996 and 1998, and the Robert H. Goddard Award in 1998. The President has honored Dr. Huntress three times, as Presidential Meritorious Executive in 1994, as Presidential Distinguished Executive in 1995 and a Presidential Award for Design of the Mars Pathfinder Mission. Dr. Huntress was awarded the Schreiber-Spence Award in 1997 for contributions to space technologies and applications. In 1998, the minor planet 1983 BH was renamed 7225 Huntress on the occasion of Dr. Huntress's departure from NASA. In 2005, his alma mater Brown University awarded him an Honorary Doctorate in Science for his professional achievements in science.

Dr. Huntress is a Fellow and Past President of the American Astronautical Society and recipient of the Society's Carl Sagan Memorial Award for achievement in astronautical science. He is also a member of American Astronomical Society/Division of Planetary Sciences, current Vice-Chair, and recipient of the Division's Harold Masursky award for service to the planetary science community. Dr. Huntress is an Academician in the International Academy of Astronautics, President of The Planetary Society, a Lifetime Associate of the National Academy of Science, and a Distinguished Visiting Scientist at Caltech/JPL.

Dr. Huntress currently resides with his wife Roseann in Rockville, Maryland. They have one son, Garret, 24.

Mr. CALVERT. [Presiding] I thank the gentleman.

Dr. Moore. The gentleman may want to turn his microphone on. The little button there.

STATEMENT OF DR. BERRIEN MOORE III, CO-CHAIRMAN, NATIONAL ACADEMY OF SCIENCES DECADAL SURVEY FOR EARTH SCIENCES; DIRECTOR, UNIVERSITY DISTINGUISHED PROFESSOR, INSTITUTE FOR THE STUDY OF EARTH, OCEANS, AND SPACE, UNIVERSITY OF NEW HAMPSHIRE

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

Last April, I appeared before this committee to discuss the interim report from the National Academy's Decadal Survey for Earth Science. That report warned that the Nation's system of environmental satellites is at risk of collapse. That statement, which may have seemed somewhat extreme at the time, was made before Hydros and Deep Space Climate Observatory missions were canceled, before the Global Precipitation Mission was delayed for two and a half years, before the NPOESS Preparatory Program was delayed for a year and a half, before the NPOESS program breached the Nunn-McCurdy budget cap, and before significant cuts were made in NASA's research and analysis account. In less than a year since our interim report was issued, matters have gotten progressively worse.

It is this backdrop that I turn to the Committee's questions.

The Committee asked me to comment on what I see as the most serious impacts to the proposed slower growth in the Science Mission Directorate.

I believe the impacts of most concern are the severe cuts in the Research and Analysis program. Cuts in R&A would be very damaging to the science and technology programs in the United States, particularly those at universities and particularly for the younger scientists.

The numerous mission cancellations, deferrals, and de-scoping that have occurred in the previous two budget cycles have already had a severe detrimental effect on NASA's Earth science. I am concerned that the new cuts in the fiscal year 2007 budget, especially the significant reductions in funding for research and analysis, could have a devastating effect on a program already pared to the bone.

I would like to address your question on the related impacts of mission delays and the issue pertaining or attracting scientists and engineers.

Two impacts of added delays are: one, there will be increased costs downstream that will further undermine the possibilities for a revitalized future Earth science program; and secondly, there will be a continued negative impact on the morale of scientists within and outside of NASA.

Reports of this impact should not be underestimated. The Committee well knows procurement stretch-outs always increase overall program costs. Moreover, moving costs forward in time for current missions in development means that there is less outyear money for the future. Once again, we are mortgaging our future.

In the interest of time, I will not discuss the particular problems that may arise in connection with the delay of the Global Precipitation Mission. They are detailed in my written testimony.

However, I do want to discuss the impact of program delays on morale and maintaining the health of a specialized workforce that is necessary to maintain core competencies.

From personal conversations, the sense of gloom and discouragement is widespread, and this is obviously connected to your important question: "At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?"

In my view, we are well past that point. Prior deterioration of NASA's Earth science program, which was discussed in the interim report, has already had an adverse impact on our ability to attract scientists and engineers. The situation will only grow worse unless there are significant improvements to the fiscal year 2007 proposal.

With regards to the Committee's second question, I will refer to my written testimony that documents the many ways the budget proposed for NASA is at odds with the key recommendations in the interim report. In fact, apart from the restoration of the Glory mission, essentially none of our recommendations were acted upon.

Lastly, the Committee asked about the balance among the various disciplines supported by the Science Mission Directorate.

Before responding, I want to note again that NASA's science programs, across the board, have already sustained deep cuts in the last two budget cycles. In fact, the cuts are, perhaps, worse than some may be aware, as recent downward modifications to NASA's operating plan make the proposed fiscal year 2007 budget cuts retroactive to the beginning of fiscal year 2006. That said, budget priorities at NASA must be balanced to reflect the highest priorities of the four Decadal Surveys.

The scientific community recognizes that much will not be accomplished in our current budget environment, but we must seek to realize the highest priority elements. I strongly support the fiscal year 2006 authorizing language charging the NASA Administrator to develop a plan to guide the science programs at NASA through 2016.

I conclude my testimony by stating my strong support, which I publicly did at the December 2005 meeting of the AGU, for the new leadership at NASA. I believe that the scientific community, as a whole, is also strongly supportive of the new leadership. However, NASA is now being asked to do more than is possible with the resources it has been given.

Though not the subject of this hearing, this situation begs for an honest appraisal of NASA's portfolio, its priorities, and whether the Nation can afford to allow NASA's science programs to languish.

I look forward to answering your questions.

Thank you very much.

[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 largely in my capacity as co-chair of the National Research Council (NRC)'s Com-

mittee on Earth Science and Applications from Space.[1] The views expressed in today's testimony are my own, but I believe they reflect community concerns. They are also fully supported by my co-chair for the NRC study, Dr. Richard Anthes, President of the University Corporation for Atmospheric Research (UCAR) and President-elect of the American Meteorological Society.

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. In response to requests from NASA, NOAA, and the USGS, the National Research Council has begun a "decadal survey" of Earth science and applications from space which is due to be completed in late 2006. The guiding principle for the study, which was developed in consultation with members of the Earth science community, is to set an agenda for Earth science and applications from space, including everything from short-term needs for information, such as environmental warnings for protection of life and property, to longer-term scientific understanding that is essential for understanding our planet and is the lifeblood of future societal applications.

The NRC has been conducting decadal strategy surveys in astronomy for four decades, but it has only started to do them in other areas fairly recently. This is the first decadal survey in Earth science and applications from space.

Among the key tasks in the charge to the decadal survey committee is the request 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.

Recognizing the near-term challenges likely for FY06 and FY07, the sponsors of the decadal study requested an examination of urgent issues that required attention prior to publication of the survey committee's final report, which was scheduled for publication in the fall of 2006. The committee's "Interim Report," "Earth Science and Applications From Space: Urgent Needs and Opportunities to Serve the Nation," was delivered to the sponsors and briefed to this committee on 28 April 2005.[2]

In the Interim Report, we stated that the Nation's "system of environmental satellites is at risk of collapse." That statement, which may have seemed somewhat extreme at the time, was made before Hydros and Deep Space Climate Observatory missions were canceled; before the Global Precipitation Mission was delayed for two and a half years; before the NPOESS Preparatory Program mission was delayed for a year and a half; before the NPOESS program breached the Nunn-McCurdy budget cap and was delayed for at least several years, and before significant cuts were made to NASA's Research and Analysis account. In less than a year since our Interim Report was issued, matters have gotten progressively worse.

It is against this backdrop that I turn to the Committee's questions.

What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?

The most serious impacts on Earth Sciences of the proposed slowed growth in the Science Mission Directorate are the severe cuts in the Research and Analysis program. These cuts would be very damaging to the science and technology programs in the United States, particularly those at universities. We all know that our country is struggling to attract students to physics and mathematics. In the State of the Union address, President Bush proposed, "to double the federal commitment to the most critical basic research programs in the physical sciences over the next 10 years." The President's proposal was part of a larger effort to "encourage children to take more math and science, and to make sure those courses are rigorous enough to compete with other nations." In my view, the cuts to NASA's Research and Analysis program in Earth Science are at odds with these objectives.

The numerous mission cancellations, deferrals, and de-scoping that have occurred in the previous two budget cycles have already had a severe detrimental effect on NASA Earth science. The table below, which is taken from the Interim Report,

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[1] *<http://qp.nas.edu/decadalsurvey>*

[2] National Research Council, *Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation,* The National Academies Press, 2005. *<http://www.nap.edu/catalog/11281.html>.*

shows just the effects of the FY06 budget.[3] I am concerned that the new cuts in the FY07 budget, especially the significant reductions in funding for Research and Analysis, could have a devastating effect on a program already pared to the bone.

Canceled, Descoped, or Delayed Earth Observation Missions (from the April 2005 Interim Report of the Decadal Survey)

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

For example, it is my understanding that approximately half of the NASA Goddard Spaceflight Center's workforce is made up of contractors. The proposed cuts across NASA for Research and Analysis funding are approximately 15 percent. In the Earth sciences, I am told that the cuts for FY07 appear to be closer to 20 percent in key elements. Since Goddard cannot reduce its civil service workforce, this cut will be magnified by a factor of two on the contractor workforce. The current contractor workforce is about 300 people and thus up to 120 people could be let go. A similar impact is likely at universities, especially as NASA will have to pay its civil servants first. Research and analysis grants will be cut; members of the community are concerned that grants already awarded might be withdrawn.

Because of the nature of the competitive process, universities, industry, and NASA centers must invest significant internal funds to prepare proposals that are compelling scientifically. Prematurely cutting missions or research awards for non-technical or cost reasons or eliminating grants after they have been awarded will have permanent, damaging consequences. The scientific community is beginning to question the reliability of NASA as a partner, and the wisdom of investing internal resources in the proposal development process.

Another impact is to reduce scientific research on missions that have already been launched and are providing novel observations of the Earth with unprecedented opportunities to learn about our planet. Cutting the research after all of the expense of building and launching the missions means that much of the up-front, and most expensive part of the mission will be wasted.

While I understand that NASA is facing difficult budgetary decisions, and priorities must be set, it would be a severe blow to NASA science to allow the R&A awards to be cut—especially given the already large investment in missions and the

[3] *Ibid,* page 17. Note that the Glory mission was subsequently restored. The latest plan for LDCM is to implement the mission as a free-flyer with a launch in 2011.

relatively low-cost, productive, and unique scientific understandings that result from these awards.

I shall return to this topic in answering your second question, but first let me address the other two components of the Committee's first question: the impact of mission delays and retaining or attracting scientists and engineers.

The impact of added delays are two-fold: 1) There will be increased costs downstream that will further undermine the possibilities for a revitalized future Earth science program, and 2) There will be continued negative impact on the morale of scientists within and outside of NASA. The importance of this impact should not be underestimated.

As this committee knows, procurement stretch-outs always increase overall program costs. Moreover, moving costs forward in time for current missions in development means that there is less "out-year" money for the future. Once again, we are mortgaging our future. In addition, delays often mean the penalties of missed synergies and gaps in observations associated with delay in execution.

For example, the two-year delay in the Global Precipitation Mission (GPM) will create a gap between its operation and that of the Tropical Rainfall Measurement Mission (TRMM), whose science operations were extended last year in part because of their valuable role in meteorological forecasts of severe weather events. The delay of GPM also endangers a carefully planned partnership with the Japanese space agency, JAXA.[4] Goddard will also be challenged to maintain a viable mission given a flat funding profile for GPM from FY06 through FY08. Project scientists are rightfully concerned that the two-year delay in GPM threatens the viability of the mission.

However, I am equally concerned about the impact of program delays on the morale of scientists within and outside of NASA and the health of the specialized workforce that is necessary to maintain core competencies. From personal conversations and anecdotal reports, the sense of gloom and discouragement is widespread, and this is obviously connected to your important question, "At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?" In my view, we are well past that point—the prior deterioration of the NASA Earth Science program, which was discussed in the Interim Report, has already had an adverse impact on our ability to attract scientists or engineers. This situation will only grow worse unless there are significant improvements to the FY07 budget proposal.

Do you believe the decisions NASA has made concerning which missions to defer or cancel are consistent with the interim report of the National Academies Decadal Survey that you released? Given the FY07 budget request, do you see any need to change the process for the next Decadal Survey?

The budget is inconsistent with the Interim Report. This is the real issue.

The Interim Report endorsed the Hydros Mission; subsequently but before the FY07 budget was released, Hydros was canceled. So was the Deep Space Climate Observatory, which was not addressed by the Interim Report, but had been supported by an earlier panel of the Academy.[5] The Interim Report stated that the Global Precipitation Mission should "proceed immediately and without further delay." The NASA FY07 action delays the mission by two and a half years.

The Interim Report not only recommended that NASA and NOAA complete the fabrication, testing, and space qualification of the atmospheric soundings from geostationary orbit instrument (GIFTS—Geostationary Imaging Fourier Transform Spectrometer), but it also recommended that they support the international effort to launch this instrument by 2008. While NOAA has completed some of the space qualification of GIFTS, the FY07 budget does not provide the additional funding that would be necessary to complete GIFTS.

The Interim Report also asked for studies regarding linking of NASA missions and plans and the NPOESS program in several key measurement areas: ocean vector winds, atmospheric aerosols, solar irradiance. We also requested an analysis of the capabilities of the then planned NPOESS Operational Land Imager (OLI) to execute the LandSat Data Continuity Mission. We have not received these studies, though we recognize that events subsequent to the publication of our report have altered the circumstances for some of the requests. However, I believe that the need for such studies has increased given the budget challenges for NASA and NOAA, the delay, cost growth, and likely changes to NPOESS, and the delay and changing

[4] Among other items, JAXA is developing the dual-frequency precipitation radar that is at the heart of the GPM mission.

[5] National Research Council, *Review of Scientific Aspects of the NASA Triana Mission: Letter Report,* National Academies Press, 2000. *<http://www.nap.edu/catalog/9789.html>.*

ideas for the development of an operational land imaging capability and implementation of the LDCM.

The Interim Report called for the release of the next Announcement of Opportunity (AO) for the Earth System Science Pathfinder (ESSP) program in FY 2005; we understand that the earliest AO for the next ESSP will be FY 2008.

Finally, in closing my April 2005 testimony before this committee, I stated that the Decadal Survey Committee was "concerned about diminished resources for the research and analysis (R&A) programs that sustain the interpretation of Earth science data. Because the R&A programs are carried out largely through the Nation's research universities, there will be an immediate and deleterious impact on graduate student, postdoctoral, and faculty research support. The long-term consequence will be a diminished ability to attract and retain students interested in using and developing Earth observations. Taken together, these developments jeopardize U.S. leadership in both Earth science and Earth observations, and they undermine the vitality of the government-university-private sector partnership that has made so many contributions to society." Unfortunately, the FY07 budget for Earth Science reflects cuts of 15 percent or more in the overall R&A program for Earth Science. We are headed in the wrong direction.

How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY07 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?

As noted above, NASA's science programs have already sustained deep cuts in the last two budget cycles. Exacerbating the cuts is the recent and not widely reported downward modifications to the Operating Plan for FY06. These cuts, which were submitted shortly after the release of the FY07 budget, make the proposed FY07 budget cuts retroactive to the beginning of FY06. The timing of the cuts makes their effect more severe; it also masks the magnitude of what is an enormous cut to the FY07 budget (because the comparison of FY07 to FY06 is now made with new, reduced FY06). Budget analyses that do not account for these recent changes leave the impression that the NASA Earth Science research budget is flat when in fact it has been decimated.

In response to the Committee's question above: Budget priorities at NASA must be balanced to reflect the highest priorities of the four decadal surveys. The scientific community recognizes that much will not be accomplished in our current budget environment, but we must seek to realize the highest priority elements. I strongly support the FY06 Authorizing language charging the NASA Administrator "to develop a plan to guide the science programs of NASA through 2016."

Let me conclude my testimony by stating my strong support, which I did publicly at the December 2005 meeting of the AGU, for the new leadership at NASA. I believe that the science community as a whole is also strongly supportive of the new leadership. However, NASA is now being directed to do more than is possible with the resources it has been given. I believe the health of science programs at NASA, which less than three months ago were said to be protected by a "firewall" from obligations to complete the ISS, develop the CEV, and return the Shuttle to flight, is in peril. Simply stated, given the NASA "bottom line" budget number and the "demands" of Station, Shuttle, and Exploration, there is far less room ($3.1 billion less in the next five years) for science.

Further, one can be reasonably sure that the pressure on science to fund underbudgeted parts of NASA flight programs will only increase—few, if any, large and complex technology development projects come in under budget. While not the subject of this hearing, this situation begs for an honest appraisal of NASA's portfolio, its priorities, and whether the Nation can afford to allow NASA science programs to languish.

I look forward to answering any questions you may have. Thank you.

BIOGRAPHY FOR BERRIEN MOORE III

Berrien Moore III joined the University of New Hampshire (UNH) faculty in 1969, soon after receiving his Ph.D. in mathematics from the University of Virginia. A Professor of Systems Research, he received the University's 1993 Excellence in Research Award and was named University Distinguished Professor in 1997. Most recently, he was awarded the 2007 Dryden Lectureship in Research by the American Institute of Aeronautics and Astronautics (AIAA). He has served since 1987 as Director of the UNH Institute for the Study of Earth, Oceans and Space. To date, Dr. Moore has authored over 150 papers on the carbon cycle, global biogeochemical cy-

cles, Global Change, as well as numerous policy documents in the area of the global environment.

Dr. Moore has served as a committee member of the NASA Space and Earth Science Advisory Committee, which published its report in 1986: "The Crisis in Space and Earth Science: A Time for a New Commitment." In 1987, he was appointed Chairman of NASA's senior science advisory panel and was a member of the NASA Advisory Council. In May 1992, upon completion of his Chairmanship, Professor Moore was presented with NASA's highest civilian award, the NASA Distinguished Public Service Medal for outstanding service to the Agency.

Dr. Moore has contributed actively to committees at the National Academy of Science; most recently, he served as Chairman of the Academy's Committee on International Space Programs of the Space Studies Board. In 1999, he completed his term as Chair of the National Research Council (NRC) Committee on Global Change Research with the publication of "Global Environmental Change: Research Pathways for the Next Decade." Currently, Dr. Moore is a member of the Space Studies Board and is the Co-Chair (with Rick Anthes, President of UCAR) of an NRC decadal survey, "Earth Science and Applications from Space: A Community Assessment and Strategy for the Future."

Dr. Moore served on NASA's Earth System Science and Applications Advisory Committee from 1998 to 2002; he chaired National Oceanic and Atmospheric Administration Research Review Team from 2003 to 2005, and he served on the Advisory Board, School of Engineering and Science, International University of Bremen from 2002 to 2006. At present, Dr. Moore's professional affiliations include the following:

- Member, Board of Trustees, University Corporation for Atmospheric Research;
- Member, Advisory Council, Jet Propulsion Laboratory;
- Member, Scientific Advisory Board, Max Planck-Institute for Meteorology, Munich, Germany;
- Chair, Steering Committee, Global Terrestrial Observing System (United Nations Affiliate);
- Member, Board of Directors, University of New Hampshire Foundation;
- Member, Science Advisory Team—The National Polar-Orbiting Operational Environmental Satellite System (NPOESS/NOAA).

DISCUSSION

FLAGSHIP MISSIONS VS. SMALL CLASS MISSIONS AND R&A

Chairman BOEHLERT. Thank you very much, Dr. Moore.

And the panel has lived up to its advance billing. It has provided a lot of food for thought.

As I mentioned in my opening, all of our outside witnesses, Dr. Cleave, indicate that NASA has made the wrong choices in distributing cuts by giving short shrift to smaller missions and research grants. Now if NASA science were to get no more than the fiscal year 2007 request, and I think that is a reasonable assumption, given the current climate on the Hill, although we are going to be working very hard to disprove that, would each of you be willing to delay or alter the flagship mission of your science field to put more money back into smaller missions and research and analysis?

Dr. Taylor.

Dr. TAYLOR. It is very difficult for me to make a categorical statement that I think represents the community in that regard, but I think that, at the very least, in the face of the apparent increases in costs associated with the top mission that NASA is now working on, the JWST, the community might well call for a reassessment of priorities. And the outcome of that, I think, should be the result of the same kind of deliberative process that has taken place in the past.

Chairman BOEHLERT. Is that something you might recommend?

Dr. TAYLOR. Personally, yes.

Chairman BOEHLERT. Okay. Thank you.

Dr. Bagenal.

Dr. BAGENAL. For heliophysics, the flagship mission is the Solar Dynamics Observatory, and—which has already experienced—was under funded. And I would certainly argue for R&A, being research and analysis—small research programs being supported over the—possibly a delay of the flagship.

My hesitation is only to say that we, as scientists, have to work with NASA and NASA engineers and industry in finding a way to keep the control of these flagship missions. The cost is a worry, and we have to find a way to do it. So I would want to put a proviso on that shifting of funds from flagships to research and analysis, which is that we work this problem out. And it will take a lot of people to make that happen.

Chairman BOEHLERT. Thank you.

Dr. Huntress.

Dr. HUNTRESS. Well, I believe that the most important elements to sustain an enterprise during very hard budget times when your expectations are ramped down, like this one, is the most important ones to keep healthy are the fundamental research programs that form the basis for solar system exploration, and secondly, the lowest cost, highest flight rate missions, so you are continually having data coming back from the solar system to support that community, and those programs need to be widely competed. And so you need to protect the small and medium-cost flight missions.

And then if we are ever to recover from loss of a flagship, we have to invest in our technological readiness for that. And so a delay in their Europa mission, if that is what it comes to, is, I believe, the right thing to do, but not at the expense of investing the technologies that will ultimately allow you to do such a mission.

What is important about the Europa mission is the science, and if we—if the current mission is so expensive that we can't accomplish that science and put it in the budget, then we can always, perhaps, try to look at another way to approach that science as well. And that is what I think Fran was talking about when she mentioned the—trying to look at the costs for these missions.

Chairman BOEHLERT. Dr. Moore.

Dr. MOORE. Well, Congressman, in delaying the flagship mission for Earth science, the answer would be been there, done that. The Global Precipitation Mission was slipped two and a half years. However, if your statement, your condition, that is no additional resources, then we have to look very seriously at what else we could do, because I do believe that the cuts for Earth science and research and analysis are just disastrous.

Speaking personally, faced with such a very difficult situation, aside from taking it from solar system, I think I would revisit the requirements for the Landsat Continuity Mission and ask is there a cheaper way to accomplish that, even though the RFP has just come out. I can think of nothing left.

Chairman BOEHLERT. That is sort of the specificity I was looking for, because you have to put yourself in our shoes for a minute. We are pretty darn good generalists. I think that is how we got here

in the first place. And we have to depend on the expertise of people like you who know so much more about the subject matter being discussed than we do. And one of the big frustrations I face in all of my years on this committee is to get the science community to help us prioritize. When all is said and done, you know, we are not really intellectually equipped to do it on our own. Now there are some exceptions. Dr. Ehlers is a distinguished physicist and others. But this guy in the Chair, you know, the last science course I took was high school chemistry. I got a C. And so that is why I am on the Science Committee. And so I—that is why we invite the most distinguished people in science to come before us to help guide us.

So let me go back to Dr. Taylor and Dr. Bagenal and Dr. Huntress. Yes or no? Would you be willing to move money out of your flagship program to put more money into research and analysis? Those are the kind of choices we face.

And Dr. Taylor, let me just add, the last time you were here, boy, did I appreciate—I mean, you gave us some specific direction. You said the Hubble is very important and not write a blank check. You gave us some guidance on a level that you would find acceptable to service Hubble. But if it goes beyond that, you said, it would deny critical—critically needed funding for other parts of your programs, and you wouldn't go beyond that. So give us more specific guidance, if you can.

Dr. TAYLOR. I am not sure what I can usefully add to what I said already. I think very strongly that if no more resources can be added to the astronomy and astrophysics budget, we are in a very tough situation and that a reassessment needs to be made about the levels of funding that are going into two things, basically now, both Hubble Space Telescope and the JWST, the two biggest sources of—or two biggest sinks of funding. And those have so weakened the other parts of the program that seem, to me, to be so essential of the future health of this scientific area that if nothing can be done about those costs, one needs to reassess whether the programs should be continued they way they are going now.

Chairman BOEHLERT. Thanks for that.

Dr. Bagenal.

Dr. BAGENAL. Let us say I would say yes that the priorities for research and analysis justify delays in the flagship. But I think what is important is that you—it is not just myself that needs to be asked, but the community. And one of the biggest problems is the lack of the advisory system that has been happening. And this is the very, very, very question that needs to be asked of an advisory group. And we hear this is going to be set up. It is going to happen. It is going to happen. It is going to happen soon. I hope it is soon, because that is the group that has to make those sort of decisions, advice to NASA, and say these are the things we need to do.

So we need that set up soon.

Chairman BOEHLERT. Okay.

And Dr. Huntress.

Dr. HUNTRESS. If there is no change from this budget prospect for the next five years, then my answer is yes, also, that I think even consistent with the Decadal Survey, that the priorities in the program under stress are first the research programs, second the

technology program, third small missions, fourth medium missions, and last flagship missions.

Chairman BOEHLERT. Thank you very much.

And I am going to take the privilege of the Chair. Usually, when the red light goes on, it applies to me, like everybody else, to be fair, but this is such an important area to cover, I want to ask for reaction from Dr. Cleave to what has just been said. And I appreciate the indulgence of my distinguished colleague, but we are on the same wavelength here.

So Dr. Cleave.

Dr. CLEAVE. Thank you.

I—first, we are putting the advisory committees together. The package is done. We are trying to plan for a meeting before June in order to be able to work these issues with our advisory committee. We have missed not having an advisory committee, too, because they are essential in this kind of advice. We are planning on working with them to look at the balance of R&A. We are doing it by division, because each division could be different, and we will take the recommendations of that committee. They, of course, always discuss it with a larger community. And then we will come in to you with an ops plan change in order to correct any problems that may have occurred.

We did take our best shot at putting this budget together. It was difficult, but it may not be the best shot that we could get with everybody's help, so that——

Chairman BOEHLERT. I understand, but now you have heard from the very distinguished panelists. Does it prompt you to rethink a few things as a result of their very valuable guidance?

Dr. CLEAVE. Absolutely. We will look into exactly what they have recommended and try to be responsive.

Chairman BOEHLERT. Okay.

Dr. CLEAVE. It is a—it is something that—the kind of tactical advice that we do usually get from our advisory committees, but we are happy to have this opportunity to get this from the panel, also.

Chairman BOEHLERT. We are on the eve of the Academy Awards, which are this Sunday, which is a plug for the motion picture industry. I am reminded of the fact that a distinguished actor won an Academy Award a few years back by uttering these famous words: "Show me the money." I think we can all agree that we need more money here. And we are going to be working very hard to get more money for science. You would expect that from us. And it is going to be a tough sell with our colleagues, given all of the competition for funding, but we are going to push them. So we are on your side.

But the fact of the matter is that we are deeply concerned by the presentation, as we see it now, and we feel that there is need for some adjustment there.

Thank you very much, and I appreciate my colleague's indulgence.

Mr. Gordon.

STATUS OF FLAGSHIP MISSION BUDGETS

Mr. GORDON. Thank you, Mr. Chairman.

We did have a pretty dire view of the future of science in NASA, which, to a great extent, is the future of science in this country through this panel's discussion.

I appreciate the Chairman's questions. Those were the exact questions in the line that I wanted to go forward, so I will extend that a little bit further.

I was impressed that the Committee volunteered, or under coercion, volunteered up their flagship missions, but I am also concerned, as Dr. Moore pointed out, does it matter. I mean, have they already been so delayed that there is not that much money there anyway?

And so, let me ask the question, did you really make a sacrifice? I mean, does it really matter? I mean, if a—can we squeeze enough money out of delaying and doing away with the so-called flagship to take care of the pure research?

And you all can—anyone that would—well, let me start with Dr. Moore. You raised the issue. Why don't you start?

Dr. MOORE. I think that is one of the real problems, because the flagship mission would be the Global Precipitation Mission, which is pushed out another two and a half years. It has been delayed in the past. It is being delayed again. There are international commitments.

Mr. GORDON. Is that just unique to you, or is it consistent with others, also?

Dr. MOORE. I think that a lot of the flagship missions have already suffered delays. Some of it is technological and some of it is programmatic. So that is why I then turn to the next item, which I find very difficult to suggest. But faced with that kind of possibility, then we have got to look further. But the cuts to R&A have got to be turned around. This is really damaging.

Mr. GORDON. Does anyone else want to elaborate on the impact of reductions or slowing down of the flagship in terms of how much that really will make—funds made available?

Dr. TAYLOR. I will just say a few words.

I don't feel competent to make judgments about the way the rebudgeting might best be done. I don't think this is the forum for making interdisciplinary decisions, as all of us have already said, or even choices among particular priorities in one of our science areas, but I do think an appropriate consultation involving NASA, possibly its contractors and certainly the scientific community, is the right way to go, and I think that—I think strongly that having appropriate estimates of costs and risks and then being willing to at least consider pulling the plug if those projections turn out not to be viable is the way to go in the future.

Mr. GORDON. Well, Dr. Cleave, I don't think that NASA should feel obligated to follow the directions of the various advisory groups, but I do think that it is important—I mean, per se. I do think it is important to get that information and to put it into the thought process. To bring them together in June really is after this appropriation process, by and large. So it is not going to be too much help. So I would encourage you to try to expedite that some.

And let me ask you, was there a discussion within NASA about so-called flagship projects and delaying more or doing away with?

And apparently you—the final decision was not to, but I mean, what was that thought process?

Dr. CLEAVE. Yes, we made—we had a lot of discussions as we were working on the budget, and we did try very hard to protect the smaller missions and get a balance. We understand a lot of people think that we got it wrong, and we will revisit that as rapidly as possible. But we did look at the flagship missions, but we tried to be guided by the decadal studies that these folks are representing. And so I don't think that we got that far off of the guidance of the decadal studies. But it is the mix that you are addressing that we may have missed on.

Mr. GORDON. And that was—those studies may have been well done under different circumstances.

The—I mean, I think it is impressive that the leaders here today would put up their firstborn to save the others. So I think that is something to take into consideration, and I hope that you will, and you need to do that fairly soon.

So again, thank you for coming. Thanks for the information. And this will help us to make our deliberations.

Chairman BOEHLERT. Thank you very much, Mr. Gordon.

Mr. Calvert.

UNFUNDED PRIORITIES

Mr. CALVERT. Thank you, Mr. Chairman.

Dr. Cleave, you have got a tough job. And being a former business guy, I know budgets are tough, and you know, I have had to make decisions in my lifetime that weren't happy decisions, and especially, I suspect, in your case where you are dealing with technologies where sometimes you just don't know what it is going to cost. You know, we are dealing with the mission to Webb and NPOESS, and obviously those programs are way out of whack as far as whatever budget analysis that was originally done. And certainly, all of the programs that were mentioned are valuable, and we would like to see them completed, but the problem is lack of money, and obviously, the Agency is making priorities and doing what they can with the money they have. I would like to see—even as a fiscal conservative, I think that science and technology is important, and I would like to see us raise the top line. That, obviously, would be the answer, because we don't like to see us pit human space exploration against robotics or other science and technology programs, but that is where we are at. Unless we can raise that top line, those are the difficulties we are in.

But you know, I am also a Member of the Armed Services Committee, and when we received the President's budget request, DOD sends us a very detailed budget, as well as those programs that are unfunded priorities or below the line.

But the national research scientists on this panel, it seems when you do your Decadal Surveys in the sciences in your field, you do a similar exercise. Do you think this listing of those unfunded priorities might be a good thing for NASA to do when it presents its budget to Congress and that way, in fact, we do raise that line or we can find some additional funds that we might be able to take a look at that?

I will start—let us start off with Dr. Cleave, and then we will just kind of come on.

Dr. CLEAVE. We do have a list of missions that we have not been able to fund within the decadal studies, so you are suggesting that we would put that list into our budget, if I understand you correctly.

Mr. CALVERT. Well, it—that we have a list of these unfunded priorities just to have that to take a look at that as the priorities as we move through this process.

Dr. CLEAVE. We could do that. It would come straight out of the decadal studies, so I will——

Mr. CALVERT. Okay.

Dr. CLEAVE. I will yield.

Mr. CALVERT. Dr. Taylor.

Dr. TAYLOR. Well, I certainly think that our long-range plan, including things that are not possible to undertake right away is a good idea. I think it is important to recognize and keep in mind that the prioritized list in the Decadal Survey that I have been involved with is one that was based on cost estimates that were thought to be valid at that time. And when costs change by large factors, almost a factor of four in one case, the reassessment of the priorities becomes something that I think is obviously necessary. And that is what I would emphasize.

Mr. CALVERT. While you are on that point, Doctor, now that is one of the problems we are having. Like, if you take the Webb, you know, we had to pull money from everywhere to replenish that.

Dr. TAYLOR. Yeah.

Mr. CALVERT. And that is the reality we are dealing with. And to——

Dr. TAYLOR. That is obviously—that is causing us to struggle and it is the root of much of the difficulty that we are all facing.

Dr. BAGENAL. When we put these Decadal Surveys together, we are prioritizing missions in terms of large, medium, and small, and we try to fit them within some kind of envelope, a budget envelope that we have—with NASA to have. And indeed, this has been the problem that doing a Decadal Survey that spans for 10 years and that profile is changing as we do the survey. In fact, what happened with heliophysics, we did two surveys. We did a survey, a full Decadal Survey, and then a year later I chaired a group that had to look at the exactly same set of priorities but with a budget that was stretched out and flattened.

So the—we should, indeed, be thinking in terms of what are the things we want to do and providing NASA with advice. And indeed, it would be useful to have those unfunded priorities listed and seen so that everyone can see what the plans are. But I would also say that we need to have some stability in the funding profiles, otherwise we can't do these plans. And maybe we need to have contingencies. You know, what if one of these big digs in space ends up being so expensive we can't afford to do it. So we need to think about that. Yeah.

Dr. HUNTRESS. Well, in fact, one of the things we do in the decadal study is—because our science desires are always larger than what we believe the pocketbook is going to be. So one of—the two things that constrain a decadal study are what is the strategic

view of what is the budget likely to be in those 10 years, and then the other are the costs for the missions that we would all like to do. And so it is a matter of putting that together in a way that fit with our view of what the budget is likely to be and to try to derive our priorities from that. And then what happens is that there are always things that we would like to do that won't fit. And in fact, in our decadal report, we actually call out what those are. These are our priorities for this decade. Here is a list of things we know we can't do under that—with those priorities and which are probably going to delay until the following decade. So we do actually do put things below the line in our decadal reports.

Dr. MOORE. One of my concerns, as chair of the Decadal Survey on Earth Sciences, which is an ongoing event, is that we started with what we thought was a pocketbook, but it has become a coin purse. And quite seriously, that is real concern. We engaged the community, but we thought we knew what the budget envelope was. In fact, we were assured to certain budget envelopes. But those envelopes have gotten smaller and smaller. And that kind of instability, I think is—makes it very difficult to do any kind of serious prioritization.

Mr. CALVERT. Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you.

Ms. Johnson.

BUDGET REDUCTIONS

Ms. JOHNSON. Thank you very much, Mr. Chairman.

Dr. Cleave, you seemed to indicate in your testimony that a $3 billion reduction would not really affect the budget that much. At what level would affect the budget?

Dr. CLEAVE. Well, the $3.1 billion that we had to remove, the—it was growth in the program that we removed over the five years did make significant changes to our plans, and that is what we are all struggling with here, so we, you know—we have prioritized what we are doing, and we are going to be working with the community. And we—at $5.1 billion a year, that is a robust science program, per se. And we do have good science to do. We are just trying to figure out what to do and what not to do, but there are definitely things we are not going to be doing.

Ms. JOHNSON. Could you elaborate just a bit?

Dr. CLEAVE. For instance, within each one of the divisions, we have had to delay the solicitation of the smaller-class missions. We try to solicit those every other year, every three years, and we haven't—we have had delays in those solicitations. The R&A funds have been reduced, and we are going to have a dialogue with the community to see if we need to restore those, but if we restore them, then we are going to have to delay other missions or, perhaps, cancel a flagship. So these are all in the trade space.

Ms. JOHNSON. What does this do overall to the space research program? How does it affect it in the future?

Dr. CLEAVE. It is delaying mainly. We have missions that we would have liked to do earlier that have had to be delayed, some of them indefinitely, which means not within this budget horizon.

Ms. JOHNSON. Are you expecting to get additional money later to pick up this——

Dr. CLEAVE. Administrator Griffin has said that this is a framework that was set up because of money that was needed to fly the Shuttle into return to flight, and this is a result of funding Shuttle needs that weren't really understood earlier. And once the Shuttle is retired, then we should not have this stress on our budget. So it should be a one-time event.

Ms. JOHNSON. I am wondering if you can submit us some data to support some of the decisions that have been made along those lines, in terms of delay, so that we can have a better understanding of how you are preparing for the future.

Dr. CLEAVE. We would be happy to do that.

Ms. JOHNSON. Thank you.

Chairman BOEHLERT. Thank you very much.

Mr. Hall.

Mr. HALL. Mr. Chairman, thank you.

And of course, we all understand that we live in tight budget times and that difficult decisions have to be made regarding agency priorities. And today, we are working on categories of funding the mission directorates. We are on science, basically, as I understand it, today. And we focus on the Science Directorate exclusively. As I understand it, Mr. Chairman, under the Administration's proposal, NASA's Science Mission Directorate would increase by 1.5 percent, I think, about a third of the total requested for all of NASA. And while this is an increase, it actually represents a decrease from what was projected a year ago.

Chairman BOEHLERT. Yeah, and the growth rate projected doesn't even factor in inflation.

Mr. HALL. And it provides $3.1 billion less from fiscal year 2006, fiscal year 2010 than was projected last year that we thought was needed.

Chairman BOEHLERT. That is correct.

SOFIA

Mr. HALL. So I guess that—and let me say this. I support Administrator Griffin and his push to get the *Vision for Space Exploration* off the ground. I am a great supporter for that.

To that end, my questions today are going to focus less on the Science Mission Directorate and the overall NASA budget and more on priorities within that directorate.

So to Dr. Cleave, formally, Dr. Cleave, and more personally to my friend, Mary, and the person that I admire and respect, and most of us do. You are wonderful. You have been there and know where the bodies are buried, so that is why I am tying into you first.

I understand that NASA has a couple of science missions that are both highly rated, and I think you know where I am going, don't you, highly rated National Academy priorities. Both of these missions involve international collaboration. And both of these are behind schedule and over budget. But one of them is 90 percent complete and over budget by a couple hundred million dollars. Is that correct? About? Close?

Dr. CLEAVE. You are—if you are referring to SOFIA——

Mr. HALL. Yes.

Dr. CLEAVE. Yes.

Mr. HALL. The one is 90 percent complete and over budget by a couple hundred million dollars. That is close enough for government work?

Dr. CLEAVE. Well, we are not—we don't have high confidence in the estimates for what it will cost to complete SOFIA.

Mr. HALL. But those are the figures that you are working with right now, aren't they?

Dr. CLEAVE. Yeah, and that is why we are going into our——

Mr. HALL. Now that is where we are, and we are there right now. And I am talking to about right now where we are.

Dr. CLEAVE. Well, it is a discussion——

Mr. HALL. Let me go further, and then you will know what I am talking about.

Dr. CLEAVE. Okay.

Mr. HALL. Both are behind schedule and over budget. One is 90 percent complete and over budget by what we contend, and my best figures are, a couple of hundred million dollars. And the other is still in the formulation phase, and it is already over budget by a billion dollars. Not underway and over budget by a billion. We have got one that is over 90 percent complete and $200 million. Maybe it is $300 million. Say it is $400 million. It could be at $100 million. Interesting, NASA has—I am told, has decided to zero out the budget for the program with the smaller overrun that is 90 percent complete and keep the program with the billion-dollar overrun that has yet to even start development. Now this doesn't make any sense to me. And that is what I really want to talk to you about. I am talking about the James Webb Space Telescope. Over budget. Massively over budget. Over a billion dollars over budget and not underway.

So—and I don't say that you have made that decision. I don't know, really, who has made the decision, but the decision that I understand has been made to zero out the budgets for SOFIA. And I have talked with you before, and I think your answer is that you are reviewing the program and that there may be more technical problems. But there may be more technical problems on the James Webb Space. There may be more technical problems in any undertaking that we have, right?

Dr. CLEAVE. There is cost growth during formulation on James Webb. That is why we try to keep things in formulation so we don't go into development too early before we understand how much it is going to cost. You are absolutely right; there has been cost growth.

Mr. HALL. It is—I think it is my understanding that NASA's own chief engineer for SOFIA, Mr. Kunt, do you know him, K-u-n-t?

Dr. CLEAVE. I have met him.

Mr. HALL. Do you have respect for him?

Dr. CLEAVE. Yes.

Mr. HALL. It is my understanding that he told NASA this week that technical problems are behind the project and that they are ready to proceed with SOFIA. For example, I understand that the structural modification is complete, these are his words, and that the telescope is completely installed and functional. Is that correct or is Mr. Kunt mistaken?

Dr. CLEAVE. I believe there is disagreement about whether it is really prepared to do flights with science collection. At the same time, there are a lot of challenges with laminar flow across an open hatch that have not—we don't have a lot of confidence in the answer yet.

Mr. HALL. All right. And you are going to try to find confidence in it. And let me see if I can't help you.

You have concerns about NASA being viewed as an unreliable partner, of course, do you know?

Dr. CLEAVE. Yes, I do.

Mr. HALL. I think that—I think you will say that they are trying to honor their commitments and that you do try to do that, and that is as we ask you to do. NASA actually has made a point of completing programs primarily to honor international commitments. For example, with Space Station, I don't compare that with SOFIA, but it is one place where we have gone above and beyond. So that—I think you are studying that. Is—that is what I am to gain from all of this question and answer?

Dr. CLEAVE. Yes, we are studying it, and we are going to be studying it with the DLR, the German space agency. And all of the options are on the table so that we can come to a good conclusion.

Mr. HALL. Can I ask Dr. Taylor? Dr. Taylor, SOFIA was ranked as a top priority in the 1991 National Research Council Survey of Priorities. And I think you mentioned this in your opening statement. Is the science SOFIA will accomplish still a priority?

Dr. TAYLOR. Yeah, it is no question that the 2000 Decadal review reaffirmed the importance of the SOFIA project that had been expressed in the survey done 10 years earlier. I think it was certainly our wish and our expectation that the SOFIA project would go ahead and would go to completion. I, too, am concerned about the aspect of SOFIA being an international project and would certainly not like us to turn out to be an unreliable partner in this case.

Mr. HALL. I take it that you are also concerned about having the project 90 percent complete and not an astronomical amount over——

Dr. TAYLOR. Absolutely. I mean——

Mr. HALL.—for finishing it?

Dr. TAYLOR. Yeah.

Mr. HALL. Dr. Cleave, can you tell me the kind of people who will be reviewing the program, the makeup of who is going to review that program?

Dr. CLEAVE. Yes, it is going to be a mix—the review team is going to be a mixture of internal and external—people internal to the Agency and external, and there will be engineers and scientists.

Mr. HALL. Internal and external, you mean NASA employees?

Dr. CLEAVE. And non-NASA employees.

Mr. HALL. And non-NASA.

Dr. CLEAVE. And——

Mr. HALL. And they will report, too, and ultimately, who will render the final decision about SOFIA?

Dr. CLEAVE. I guess I will.

Mr. HALL. Well, I want to talk to you more. My time is about up.

Thank you, Mr. Chairman.

Chairman BOEHLERT. And thank you.

Mr. HALL. Thank you, Dr. Cleave, and thank you, Mary.

Chairman BOEHLERT. Mary and Ralph are going to get together, I can see that.

Mr. HALL. We are going to get together.

Chairman BOEHLERT. All right.

The Chair recognizes Ms. Hooley.

EFFECTS OF BUDGET CUTS ON CLIMATE CHANGE

Ms. HOOLEY. Thank you, Mr. Chair.

Mr. Moore, in your testimony, you made the claim that the budget analysis leaves the impression that NASA's Earth science budget has been—remained flat while you claim it has been decimated. Can you explain to this committee how could there be such an extreme difference between what the budget analysis says and what you say actually occurred?

Dr. MOORE. No, I can't. I mean, I simply know what I read in the budget and what the Committee is telling me, look at what the operation plan did, and I look at the actions of the delays in the missions. For instance, it was just said in an answer to Congresswoman Johnson about having an Explorer class mission every other year or maybe every three years, Dr. Cleave said that the next Explorer class ESSP will be 2008 for Earth science. Well, the one before that was 2001. So we have already been in trouble since 2005. And so this is just trouble piled upon trouble.

Ms. HOOLEY. One of my interests is climate change. Can you summarize how the proposed budget would affect NASA's work on climate change? And what are the three most important things we need to do to ensure the Earth observation programs remain viable?

Dr. MOORE. Let us start with a little bit of good news——

Ms. HOOLEY. Oh, good.

Dr. MOORE.—because there hasn't been much. NASA has decided to go forward with the Glory mission in Earth science. That had previously been cut, and that deals with aerosols, which are a very important part of the climate question. I want to compliment the Agency going forward with that.

Now for the concerns.

The key mission that was to link the long-term observations of the EOS period, the outyear missions to be covered by NPOESS, granted that NPOESS has got its problems, which I will go to——

Ms. HOOLEY. Right.

Dr. MOORE.—but that piece that was to go in between was the NPOESS Preparatory Program. That is continuing to slide downstream, as is the NPOESS program. So we are going to lose that connectivity between the EOS program and the long-term NPOESS program. And I think that is a very serious problem. It is not NASA's doing totally, but it is a serious issue.

And finally, I think that without the research and analysis effort, I know Congressman Rohrabacher has some serious questions about climate change. Now what you really get at that is not just through observations, but it is through the very best in science. There are very tough questions associated with climate change:

cloud water feedback, things like that that are very difficult. That will require the very best science training this country can produce. That is why R&A is so important.

Ms. HOOLEY. Thank you.

Dr. Cleave, I know that NASA may have higher priorities, but when you were working on the budget, where did NASA's climate change program rank within the larger budget?

Dr. CLEAVE. Our priorities for working this budget, we tried to rebalance the program. There was a larger Mars wedge—and Wes is probably not happy with this decision, but we had—there was a Mars wedge that was built. The money had been taken primarily out of Earth science and heliophysics with a little bit out of the universe, and we have tried to put that money back into the various programs.

So there—it actually ended up gaining money through this budget cycle, obviously not enough to fix some of the real issues that we saw with the budget, but there was that rebalancing. So if—you can look at it—actually, planetary science lost more money, as Wes stated, and then the other disciplines gained a little more.

COORDINATION WITH NOAA

Ms. HOOLEY. Dr. Cleave, the—you know, we are making cuts to Earth's observation satellites. How is that being coordinated with NOAA? And how do we ensure the improvement of the next generation of sensors that are now in the development for the new geostationary weather satellites NOAA is beginning to design?

Dr. CLEAVE. We have a working group with NOAA, and we discuss these on a regular basis. That is run out of our Earth science division. They are making plans for transitioning measurements into the operational system. The—NPOESS, actually, is a demonstration of how EOS instruments transitioned into the polar-orbiting weather satellites. And we will continue to try to support that.

Ms. HOOLEY. All right.

Thank you, Mr. Chair.

Dr. Moore, do you want to comment on what she just said?

Dr. MOORE. I think that—and this ties to something that Wes Huntress, and I think others, have eluded to is that not only are we de-scoping and delaying missions, but we just—in this budget environment, we do not have the capabilities to make the kind of technological investments that we have got to do. And as a consequence, we are, in some sense, endangering the outyear efforts of our sister agency, NOAA. I think we really have an extremely serious problem, and respecting the Chairman's point of view, I don't think we are going to get there by rearranging the deck chairs in the science program. I think that something more fundamental is going to have to happen.

Ms. HOOLEY. Thank you for your comments. I appreciate it.

Chairman BOEHLERT. Thank you very much.

Mr. Rohrabacher.

ENERGY R&D VS. NASA R&D

Mr. ROHRABACHER. I want to thank you very much, Mr. Chairman.

Well, from what I see, it appears that the budget isn't necessary being slashed. The growth of your budget is being slashed from 1.5 percent increase is what you will be receiving as compared to what was expected was a 3.6 percent increase in your overall budgeting. Is that correct, Dr. Cleave?

Dr. CLEAVE. Yes, we expected more growth in our budget.

Mr. ROHRABACHER. Okay.

Dr. CLEAVE. $3.1 billion was removed.

Mr. ROHRABACHER. Okay. And that—with the inflation rate of approximately three percent, so we are actually talking about, perhaps, an actual cut, in real dollars, of 1.5 percent. The President announced in his State of the Union that he would—15 priorities of this country and that a—now a priority would be, for the rest of his Administration, if not for the following Administrations, would be the development—the use of technology dollars to develop energy self-sufficiency for the United States. I would assume that there has probably been a shift of resources here. If you have to identify where that money went, why this 3.6 percent was not—is not here, I would assume that that is where it is going. I would just like the panel's, you know—or your opinion of what the President of the United States has done here. Is this not a logical thing for us to do at a time like this? And should you not also be doing your part to help in this—you know, energy self-sufficiency now is a—is what? It is a national security issue. People are dying because we are not energy self-sufficient. Shouldn't you pay a—maybe a little bit of a price of helping to achieve that noble goal, or is this not as noble a goal as expanding the understanding of the universe?

So just——

Chairman BOEHLERT. Dr. Bagenal, you wanted to——

Dr. BAGENAL. Please.

Chairman BOEHLERT.—observe? I mean——

Dr. BAGENAL. This spacecraft here, which is about the size of a piano, a grand piano, which is on its way to Pluto, it will be——

Mr. ROHRABACHER. It is from what? Now excuse me?

Dr. BAGENAL. It is the New Horizons mission to Pluto.

Mr. ROHRABACHER. Yes.

Dr. BAGENAL. It is on its way to Pluto. It is actually just about across the orbit of Mars. It is on its way.

Mr. ROHRABACHER. Okay.

Dr. BAGENAL. And when it gets there, in nine years time, it will be using energy to power this entire spacecraft, take pictures, send the data back across 30 times the distance between the Earth and the sun, and it will be using a total power of 200 watts. That is two 100-watt light bulbs. And so we are acutely aware of energy efficiency in NASA. Those of us who are involved in space missions——

Mr. ROHRABACHER. It sounds like you are ready for the question, too.

Dr. BAGENAL. Well, it is something that I am—I wasn't ready for the question, but I—it is something we are very aware of. And so I think one of the things which NASA doesn't get credit for is the fact that—or it doesn't, perhaps, get enough credit for, is the fact that working on these space missions allows us to work very hard on very, very tough technical problems. And one of them is energy. It is very, very important. Energy is one of the big, big things we have to worry about. And so we develop instrumentation, small instrumentation, very energy-efficient instrumentation, how to protect things and keep them warm without using energy and so on. So I would like to—I think that these small experiments that we do and that we send out into space actually do teach us a lot about how to save energy, how to use it wisely.

Mr. ROHRABACHER. All right. But do you think that that—you are talking about a spin-off technology that——

Dr. BAGENAL. Yes.

Mr. ROHRABACHER.—will affect—that will have a positive impact? Do you believe that—and of course, we will let your other panelists answer as well. But you are saying that that is, perhaps, as important to achieving the goal or at least measurably important to achieving that goal as taking that same money and investing it directly into a technology program that, for example, would turn grass cuttings into clean energy, because that—obviously that is one of the things the President has in mind?

Dr. BAGENAL. Well, there are two approaches to energy conservation. One is to how to generate energy and the other is how to try and use less.

Mr. ROHRABACHER. Oh, okay.

Dr. BAGENAL. And so the space business, particularly, has to worry about how to use less. And so I do believe that there are lessons that we learn from space exploration that benefit here as—on Earth on how to conserve energy——

Mr. ROHRABACHER. And it has a——

Dr. BAGENAL.—on the Earth.

Mr. ROHRABACHER. Okay. That is good. That is good.

Chairman BOEHLERT. Thank you very much, Mr. Rohrabacher.

I think what many in the science community would argue is that this science portfolio is being denied needed resources so if those resources can be directed toward the Shuttle and Station, that is, I think, the general argument within the community. And what we are trying our level best to do is face up to the reality. We have a $16.8 billion budget request, and we are trying to determine, within NASA, how those dollars should be allocated. And that is why I think this panel is so critically important to our deliberations. There are some who feel, as I indicated earlier, that too many resources are being allocated for the Shuttle and Station and not enough for science, not enough for aeronautics. So it is a tough battle.

Mr. ROHRABACHER. Would the Chairman indulge me in a non-global warming question for the panel?

Chairman BOEHLERT. Well, do you mean that we can count you in the believers?

Mr. ROHRABACHER. You mean we have already finished——

Chairman BOEHLERT. Mission accomplished.

NEOs

Mr. ROHRABACHER. But I—if—with the Chairman's indulgence, last year, NASA's authorization bill amended the—NASA's mission to include the cataloging in characterization of near-Earth objects, such as comets and asteroids. And this happens to be something that, I believe, again, like whether we are talking about energy self-sufficiency or we are talking about the possibility that something could hit the Earth and kill millions of people, that this is—these are tangible—not just expansion of knowledge, but a tangible thing that we have to deal with and that—what will affect people's lives, or could well affect millions of people's lives. Where does this play in the budget now, Dr. Cleave? Is that—and are we going to be implementing this, or is this one of the things that are cut from—or is it scaled back because of the budget?

Chairman BOEHLERT. The gentleman's time has expired, but Dr. Cleave, we will give you the opportunity to respond.

Dr. CLEAVE. Thank you.

The—we have an ongoing survey that was previously under conduct, and the—we are looking very carefully at the language. The change that has happened within the Agency is that Administrator Griffin takes this issue very seriously, and he thinks that our agency should be looking at it seriously, and not just in science, because it is really—what you are talking about really is not a science investigation, per se. So we have a team of people looking into this that is not just within science, but also within exploration and space operations.

Mr. ROHRABACHER. Well, I would disagree. I think this is pure science, and it is the kind of science that really helps—that people—regular people can understand. And we are grateful for technologists who are doing things that protect us from viruses, from near-Earth objects, and perhaps, even from global warming, but we will talk about that later.

Thank you very much.

Chairman BOEHLERT. Thank you for your always interesting interventions. We appreciate it.

Mr. Green.

MONEY LOST IF/WHEN SOFIA IS CUT

Mr. GREEN. I thank you, Mr. Chairman.

I thank the Ranking Member and the members of the panel.

And Mr. Chairman, I want to assure you that you are not the only person to "C" your way through science in high school.

I was—I had a great degree of pessimism with reference to SOFIA until I heard that Dr. Cleave indicate that she is the person who will make the final call. And now I am a bit more optimistic, Dr. Cleave, knowing that you will make the final call. However, I noticed that we have a four-to-one ratio here today, so our colleague, Mr. Hall, may need some support when he visits with you, and I would be honored to be a part of that support team, if permitted.

I am as concerned as Mr. Hall is about SOFIA. And as I look at the numbers, I possibly come to the same conclusion that he has come to. I think we have about a $500 million investment. The

Germans have a $100 million investment. We need about $90 million to complete the program. It is 85 to 90 percent finished. If we zero this out, literally, do we just conclude that we have lost $500 million? Dr. Cleave.

Dr. CLEAVE. Well, there are different ways to look at programmatic issues, in a sense. SOFIA has seen a 47 percent cost growth: 40 percent cost growth in operations, 17 percent reduction in the science return from the flights. The—unfortunately, very unfortunately, because of the delay, we are not going to have the two-year, at minimum one-year overlap with Spitzer, which was part of valuing the science, and also with Herschel [ph] being launched by the Europeans, we won't be ahead of that in a way that would have put greater value on the science. So that is why we are having this review, and we are going to look at it very carefully.

SOFIA'S FUTURE

Mr. GREEN. It would seem to me, then, that we would need to move as expeditiously as possible, given that we are falling behind, and if we are going to do this, we might want to aggressively pursue it. And in so doing, let me ask this. What factors will you look at if you had, say, one, two, or three that would help you in determining whether to continue with the program?

Dr. CLEAVE. Well, this will be a dialogue with our international partners. We are looking for different options we may have to continue the programs in ways that weren't planned for originally. So it is not—we are looking at the different options dialogues, and then we will hopefully all come to consensus on that, and I will get a clear recommendation. If not, you know, we are going to have to discuss it further. But we are looking seriously at the science return along with the costs.

Mr. GREEN. And we do agree that we need about $90 million to complete the program?

Dr. CLEAVE. We are—we don't have a lot of confidence in those numbers, because there are still significant challenges, we believe, to completing this space crafting and getting it certified and flying it and getting science quality data from the telescopes.

Mr. GREEN. Would anyone else on the panel care to respond?

It seems that a four-to-one ratio is about right, Dr. Cleave.

Thank you, Mr. Chairman.

I yield back the balance of my time.

Chairman BOEHLERT. Thank you very much.

Mr. Wu.

Mr. WU. Thank you very much, Mr. Chairman.

The Chairman and the Ranking Member have asked such penetrating questions about the choices that you all have to face. I really want to expand beyond that, and I don't have so much a question to ask as a statement to make, and—looking at the future guided by the past. And it is going to be a short history lesson. It is only going to go back 500 years.

Something very important happened in 1492. The last Moorish stronghold in Spain, Grenada, fell. And incidentally, Ferdinand and Isabella sent an Italian fellow out on the ocean and—looking for something that—well, he was really looking for something else, but

he found , roughly, this place and established the greatness of Spain for the next 200 years.

Fast-forward a few hundred years, around 1800, and Thomas Jefferson, he sent off a fellow from Ivy, Virginia and another fellow named Clark, gave them an appropriation of $2,500. They came back. They were a little bit behind schedule. They were a little bit over budget. They spent $34,000 to reach the Pacific and come back. And President Jefferson was taken to task for that incredible cost overrun.

And then the last stop I would like to make before getting to the subject of the day is I believe it was in 1862 that this Congress and President Lincoln, a great leader, decided to, A, finish the dome of the Capitol, B, complete the trans-continental railroad, and C, pass the legislation that created the land grant colleges.

Those were all very challenging times. When the dome was completed, the railroad that knit this continent together and the future of this country was created by those land grant colleges. You could literally hear Confederate gunfire from this site. When Thomas Jefferson sent Lewis and Clark out on that transcontinental mission, I don't know if he had paid off the bonds that had funded the Revolutionary War yet. And when Columbus was set forth by Ferdinand and Isabella, the Spanish had just finished up a 500-year war with the Moors.

You all should not be made to choose between your lead projects and holding up basic science and the small projects. To sort of borrow from the Chairman's movie reference earlier: "What we have here is a failure of vision." What we have here is a failure of leadership. You should not be made to make that choice. The choice is made up here on this bench and down the street at Pennsylvania Avenue.

And I will tell you this. I will vote tomorrow to stop the bleeding in the Middle East. I will vote tomorrow to rescind these stupid tax cuts that we passed in 2001. And I will vote tomorrow to put this country back on a course that allows us to do the things with our own people and not have to eat our seed corn, as you all are being forced to do today.

This is a failure of vision. It is a failure of leadership. And I have put up with it for five years, but I am mad as hell, and I am not going to sit here silently anymore. There is an election in 2006. There is an election in 2008. And the tax cuts expire in 2010. Public decisions have real consequences.

And Mr. Chairman, with your indulgence, I know you love baseball. I think—I love fishing. I think we spend about $60 billion a year in America on recreational fishing. If we could—you know, I want to see sports fishing continue, but if you had a budget like that, you could do all of the things that you wanted to.

Mr. Chairman, I don't know how much is spent on baseball in this country, but if we spent about the same on the space and science as we do on baseball, by God, you all would be able to do your mission. Public decisions have a consequence. The people of Portland, Oregon failed to build a professional football stadium. The bond measure failed by less than 100 votes in the mid-1960s. And if we had built that stadium, we wouldn't have to cheer for a sad sap team from Seattle, Washington.

Leadership comes from here and from down the street. You shouldn't have to make this choice.

Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you, Mr. Wu.

The Chair would observe that we are not in session tomorrow.

The Chair recognizes Mr. Honda.

ASTROBIOLOGY

Mr. HONDA. Thank you, Mr. Chairman.

Nice job, David. I feel like whatever I am going to say is going to be inconsequential, and it diminishes itself just in the light of what you just said. And I would also align myself with your comments, Mr. Wu.

My question is around astrobiology.

Dr. Cleave, the fiscal year 2007 budget request proposes a 50-percent cut for astrobiology on top of the significant cut made in the current fiscal year 2006 operating plan. And this cut is much larger than the 15 percent across the board cuts to other science programs within the research and analysis budget.

To me, these actions seems completely out of sync with the National Research Council's recent report entitled "Life in the Universe," and—which was requested by this committee. Can you explain why you have disregarded the findings of the National Research Council in this case? And can you also explain why astrobiology was singled out in this manner, especially given the interest of Congress in this field as a priority for the science—space science program and the extreme relevance of this work to the scientific and philosophical—excuse me, philosophical basis for the entire *Vision for Space Exploration,* which was supposed to be about going to Mars, though I didn't hear too much about that anymore? I would be very interested in your response.

Dr. CLEAVE. Yes. In the context of slowing down the missions to Mars as we redistributed the program funds back into the other divisions, and in light of, you know, not going to Europa or the outer planets as rapidly as we expected, and in light of the very rapid increase to astrobiology that had occurred, those all factored into why we made the decision to slow astrobiology down. I know a lot of people don't agree with that decision, and this is another decision that we will be working with the advisory committees and we can revisit and come back to you on.

Mr. HONDA. And Dr. Huntress, thank you.

Dr. HUNTRESS. Let me just rebut that a little bit, because, in fact, the astrobiology program is not all about Mars. In fact, most of the work—a great deal of it anyway, of the work that is done in that astrobiology research program is done on the Earth, on our own planet, trying to understand, in fact, extreme forms of life that live in very extreme environments, even on our own planet, in hot springs, in seed pools in Yosemite, trying to understand how life got started on this planet, how it evolved, in order to be able to know enough to look for it elsewhere. And you just can't turn science off and then turn it back on again. Once you turn a science off, it is—it takes a long time to recover it. And I would like to point out that we are still sending missions to Mars every 26 months.

Mr. HONDA. And your example about going to different parts of our planet and looking at different conditions does make a lot of sense, because there are different conditions that we find, including, you know, deep sea where there is a lot of pressure and there is no light and the kinds of hot water where we think that nothing would survive in, we see algae and other things that are out there, so I concur with your analysis and your conclusions. And I also agree that, you know, as a science teacher, you know—I am just a humble science teacher, but it seems to me that, you know, turning something off and turning it on, the efficiency and the impetus that you—we want to maintain would be lost in that. And so I subscribe to your position, Dr. Huntress, and would ask Dr. Cleave to look at that and revisit that decision.

Dr. CLEAVE. Yeah, we will be looking into that.

Mr. HONDA. Thank you.

Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you.

THE EFFECTS OF THE FY07 BUDGET REQUEST

Let me—Dr. Cleave, let me give you a little rest a little bit, and listen, as I will, to the answers.

I would like each of our non-NASA witnesses to describe the single most significant scientific question that you think we will not be able to answer or answer in a timely fashion if the fiscal year 2007 budget proposal is approved as is. Now that is a toughie. Let me repeat the question, because I always have to have questions repeated a half a dozen times to me. Describe the single most significant scientific question that you think will not—we will not be able to answer or not be able to answer in a timely fashion if the budget goes forward as is.

Now I am going to give you a little bit of time to think about it. It is just like on TV with one of those game shows. So the clock is ticking.

Dr. Huntress, do you want to——

Dr. HUNTRESS. Mr. Chairman, let me just jump in here, I mean, and tell you what came right to the top of my mind which is that one of the questions that human beings have been asking themselves ever since, you know, they crawled out of caves, is whether or not they were alone in this—on the planet. And now we are asking ourselves: "Are we the only form of life that there is?" "Was there ever life anywhere else in our own solar system?" I think that this budget proposal will short-circuit our ability to answer the question in the next 10 or 15 years as to whether or not there was really life any—at any time elsewhere in this solar system.

Chairman BOEHLERT. Would it mean that it would be a next—instead of 10 or 15, 11 or 16? I mean, I——

Dr. HUNTRESS. Well, what I worry about, of course, is once you short-circuit that sort of science and the engineering approach to that, it is difficult to recover it. And what we are—what this budget is setting a new pattern for the Agency in terms of what it is willing to invest in scientific exploration versus what it wants to invest in human space flight. And we have been told that after the Shuttle is terminated in 2010, if you believe 2010, I don't, that science will be given a recovery, will recover from that. I don't be-

lieve that, either, because we will find a pattern will have been set and we will spend it on what comes after the CEV. So I think it is difficult to recover once you have made your patterns—set your patterns.

Chairman BOEHLERT. Thank you.

Dr. Taylor.

Dr. TAYLOR. I should preface saying anything by saying that I believe very strongly that the community consensus input is the most important one.

But you are asking for a quick answer now from individuals, and I will give you mine.

I would be very sorry if the present budget stayed as it was and prevented the completion of two particular projects, one having to do with the detection of gravitational waves with a space interferometer and another having to do with exploring the nature of dark energy that fills the universe.

Now I emphasize, again, those are my own personal wishes, and they would not necessarily be echoed by all others in the community, but they were things that are highly rated, and we very much would like to see go forward.

Chairman BOEHLERT. Do you share Dr. Huntress' concern that you think we are just changing dramatically the pattern? And do you have the same pessimism about completing the Shuttle by 2010? And——

Dr. TAYLOR. I do, and I think that is consistent, also, with the concern over the fact that so large a portion of a necessary budget is going into a few particular things, like the Shuttle, in particular.

Chairman BOEHLERT. Thank you.

Dr. Bagenal.

Dr. BAGENAL. Heliophysics involves trying to understand how activity on the sun impacts humans on the Earth, our livelihood here, as humans, and our activities in space, either human exploration or all of the satellites that we operate in space. And so one of the things we try to do in heliophysics is to predict the space weather and what happens when something happens on the sun and the impact.

Now to understand this process requires multiple components, multiple spacecraft, and we use many methods of approaching this. And so it is a little difficult to say, you know, one simple thing that we won't be able to do better. But I will say that one of the things we relied upon is the innovation that comes out of the Explorer program and the new missions that come from that. And my concern is that the one thing that is going to happen is if we have no more Explorer missions, those innovative methods of trying to understand the connection between the sun and the Earth will be impacted not just this time, this year, but for decades.

Chairman BOEHLERT. Thank you.

Dr. Moore.

Dr. MOORE. I think that Wes Huntress put it correctly, that we are at a tipping point. And all of a sudden, if we go forward with this 2007 budget, not the one scientific question we won't answer this year, those decisions that are going to be made by the graduate students and the undergraduates that are coming along that

will say, "No, I am going to go do something else. This country is not interested in Earth and space science."

Chairman BOEHLERT. We constantly hear that if we do anything to change the investment in the Shuttle and the CEV and the Space Station that we will lose a core competency that we will never be able to recapture. One could make the same argument in all of your various disciplines. Is that fair to say?

Thank you very much.

Mr. Lipinski.

OFFSETS FOR SOFIA

Mr. LIPINSKI. Thank you, Mr. Chairman. I apologize for missing some of the hearing. I had another hearing that I was attending, but I did—very happy I got to hear the responses to the Chairman's question there at the end that really get to the heart of the matter, and I think we are all concerned about the future of space exploration right now. And it concerns me that we are at that tipping point, and as Dr. Moore was talking about, especially with getting young people interested and involved in getting people and getting our students to go into these areas in college and beyond that.

Now I want to get back to something that was talked about a little earlier, but I wanted to talk a little bit more about it and ask Dr. Cleave a little bit more about it.

The SOFIA program, I am particularly interested in this, because at the University of Chicago, they are developing the high-resolution airborne wideband camera, or HAWC, to—as part of the SOFIA program, and it is going to provide some of the sharpest—if we go through with this, provide some of the sharpest images ever of our universe. But it also has a connection, I know, with the community in with education, because at the University of Chicago, they have reached out to the K–12 schools and teachers and reached out to the community to really get people involved, push to get young people involved and interested in space and interested in this project and the telescope.

So I just wanted to ask. Dr. Cleave, is this—how unusual—first of all, how unusual is this to zero-out a program like this while it is still under review? And second, where do you think the money is—if it does—my understanding is, if the review says to go through with this and it is near completion already, I expect that it will, where is the money going to come out of? What is going to be short-changed if the decision is made, then, to shift the money over?

Dr. CLEAVE. Well, within the SOFIA program, if the review decides that we need significant funds, I mean, we did zero the budget so we didn't have to hit anything else, that had come through confirmation cleanly, this—again, SOFIA has had a 47 percent cost overrun, significant delays. Programmatically, it is a program in trouble, and we are, because of budget constraints, going to have to be much more strict about keeping programs under control. Most likely, we would be looking at another Explorer program that we would have to terminate within that line. That is what we expect.

Mr. LIPINSKI. Okay. I want to thank all of you for your testimony. I look forward to going over and reading that. And I just

want to emphasize, and I am sure everyone else has here on the Committee, how important we believe that this is and we will all be working and fighting for an increase in the funding, because it is—I am a—have a background as an engineer, but I was also a professor. And I am very interested in education, and I think this really goes, you know, to learning more and helping to educate our future and keep our country on the cutting edge of research and exploration.

Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you very much, Mr. Lipinski.

And now as Martin Agronski used to say, for the final words, Mr. Gordon.

SCIENCE VS. HUMAN SPACE FLIGHT

Mr. GORDON. Just in time. I will let the bells finish up here.

Well, Mr. Chairman, with the exception of David Wu's history lesson, I have to say this is probably the most depressing hearing that I have sat through. It amounted to trying to determine which of your children are you going to throw off the boat to save the boat, and I think it degenerates to the point that we are going to throw them all off to save the boat. It looks to me like we are heading down the course of a humpty dumpty NASA budget and that we could very well have difficulty putting NASA back together again if we are going to wind up losing the graduate students, the scientists, and other skilled personnel. And I think we have all ignored the elephant in the room, and that is how do these science programs stack up against the President's initiative, the lunar mission? I think many of us would like to think that the CEV would be operational by 2010, but I don't think many of us believe that is going to occur. And whenever it does occur, there is going to be additional cost. So I would give the panel the opportunity to—and since we are making hard choices here, how do these science hard choices pit against the lunar mission in terms of pushing that back or making those changes?

Who wants to start?

Dr. HUNTRESS. Well, Mr. Gordon, I actually believe that what you called the lunar mission, or the fixes to human space flight that Administrator Griffin is trying to do, and it is a program that needs to be fixed, I think they face a problem, too. I don't—they have been given enough money. For example, NASA's architecture for going back to the Moon has been called "Apollo on steroids." Right now, given the budget that they have got for the next five years, it seems to me it is "Apollo on food stamps."

Mr. GORDON. Well, it is $5 billion under funded.

Dr. HUNTRESS. I agree with that. In fact, at a hearing of this committee, in October of 2003, Mike Griffin and I sat right next to each other. And we were asked by Congressman Rohrabacher what we thought NASA's budget needed to be in order to fix human space flight and go beyond the Station and start exploring again. And both of us said—gave the same number. We both had had it written down and showed it to each other. And that was $20 billion a year. Then we were asked by Congressman Rohrabacher, "Would you give up science to do that?" My answer was no. Mike's answer was yes.

Mr. GORDON. Okay. And I assume it still is. Okay.

Would anyone else like to comment?

Yes.

Dr. TAYLOR. I would just say that my answer would also be the same as Wes gave, and I think if—well, I—in my own view, the going back to the Moon initiative has not been adequately motivated or ever compared to the other things that NASA already has underway. But from my own point of view, if I were sitting in Mary's position, those are the questions that I would be asking very strongly within the Agency.

Mr. GORDON. Dr. Moore.

Dr. MOORE. Congressman Rohrabacher, unfortunately, has left, but he was suggesting that perhaps money from the Department of Energy and NASA were fungible in some way. If they were, I might, then, ask is there money that is fungible between State Department and NASA, because quite frankly, when I look at Station, the primary argument is one of an international collaboration. I don't see a scientific justification. So I think that we really have to step back and look at the entire spectrum of priorities that NASA is facing. And when asked the question, "What is the budget that we need to execute this?" We are not doing that, and we need to.

Mr. GORDON. Do you want to say "Amen" or are we going to go on?

Chairman BOEHLERT. Dr. Bagenal, do you have a——

Dr. BAGENAL. Well, all I will say is I would really like to speak on this, but I will say that when I ask my students, I have 200 students in astronomy, University of Colorado, average people in the United States, taxpayers, or soon to be when they start earning some money, you are going back to the Moon, and they all say been there, done that. It is, you know—it is—for them, they don't want to—they are not so interested in going to the Moon, but they are interested in going to asteroids. They are very interested in going to Mars. And we—I have also believed that there are things that can be done with Station. Maybe Station is the weigh station. Not to Mars. Not the Moon. So that is what they are concerned——

Chairman BOEHLERT. Thank you, and very timely, because we have to go over to the Floor.

Thank you all very much. I hope you have gained something from this, Dr. Cleave, and I hope all of you feel that this whole exercise has been worthwhile. You have shed some new light in areas that I think we have to look at more closely.

Thank you very much. This hearing is adjourned.

[Whereupon, at 12:20 p.m., the Committee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mary L. Cleave, Associate Administrator, Science Mission Directorate, National Aeronautics and Space Administration

Questions submitted by Chairman Sherwood L. Boehlert

Q1. Dr. Cleave, you stated at the hearing that you would go back and look into the balance of funding for flagship missions versus research and analysis (R&A) and smaller missions. When will this reassessment be complete and how will you inform Congress of your decisions? What factors are you going to take into account when reassessing the funding balance?

A1. We intend to discuss this issue further with the NASA Advisory Council (NAC), with representatives of the science community and the Space Studies Board of the National Academy of Sciences, and will seek their advice to ensure that we maintain an appropriate mix within each Science Mission Directorate (SMD) Division between R&A, small-, medium-, and large-class missions. The Space Studies Board met March 6–8, 2006, and their report *"An Assessment of Balance in NASA's Science Programs"* has been received and is currently under review. The science subcommittees of the NAC met May 3–4, and the Chairs of each subcommittee sent recommendation letters to the Science Committee Chair. These subcommittee recommendations were discussed at the NAC meeting on May 18 at the Jet Propulsion Laboratory, and NASA anticipates receiving formal recommendations for SMD within the next few weeks. Should changes in the mix of R&A and mission investment be determined to be appropriate, we may pursue that course of action, and notify Congress via an adjustment in NASA's FY 2006 Operating Plan and NASA's initial FY 2007 Operating Plan.

Q2. When do you plan to have an advisory committee for NASA Sciences set up? You said at the hearing that NASA is planning for a meeting of the Advisory Committee before June. Why can't a meeting occur earlier?

A2. In the new advisory system established by Administrator Griffin in late 2005, the main science advisory body is the Science Committee of the NASA Advisory Council. The Science Committee has met three times, in November 2005, February 2006, and May 2006. In parallel, NASA has been working to establish five discipline-oriented subcommittees that will advise the Science Committee. The first meeting of four of these subcommittees, which are focused on astrophysics, heliophysics, Earth science, and planetary sciences, occurred during the first week of May.

Q3. When developing the FY 2007 Science Mission Directorate budget, was funding first allocated among the different divisions or did you begin by evaluating missions across the entire directorate? To what extent did you consult with the scientific community in determining how to distribute the available funds?

A3. Funding was initially allocated among the science themes to further implement the balancing of the science portfolio begun last year. Each division was responsible for determining the mix of missions and R&A, using input from science community as reflected in the decadal survey and Space Studies Board reports to guide this process. Final approval of the proposed budget is the responsibility of the Associate Administrator for Science Mission Directorate.

Q4. NASA recently announced that Hydros, a previously approved "alternate" ESSP mission, was not selected for confirmation. Over the past few years, numerous NASA documents and communications have listed Hydros as if it were an approved mission, with an expected launch in 2010. (These indicators and NASA guidance caused members of the Hydros team—including U.S. agency and international partners—to commit to support the mission and realign some activities in this direction.) Similarly, NASA has announced the cancellation of the NuSTAR mission for budgetary reasons, just weeks from its confirmation. Is there a way that NASA can change its procedures so it does not create false expectations about which missions are approved?

A4. All of the competed, Principal Investigator-class mission lines—Discovery, Explorer (such as NuSTAR), Earth System Science Pathfinder (ESSP) (such as Hydros), Mars Scout, and New Frontiers—include a series of competitions, down-selects, and confirmation reviews. All proposers understand that these are heavily oversubscribed flight opportunities, and that NASA must make difficult decisions based on scientific, technical, programmatic, and budgetary considerations at every

step of the process. NASA describes these processes and procedures in each Announcement of Opportunity, and it is appropriate that we should strive to be as clear as possible in future Announcements.

The Hydros mission was selected as an alternate mission to the Orbiting Carbon Observatory (OCO) and Aquarius missions. The ESSP budget is only sufficient to support two flight missions. After OCO was confirmed to proceed to implementation in May 2005, and Aquarius was confirmed to proceed to implementation in October 2005, it was no longer possible to continue supporting development of the Hydros mission.

Following a competitive Phase A mission concept study involving five Small Explorer (SMEX) missions, the Interstellar Boundary Explorer (IBEX) was selected to proceed into Phase B preliminary designs and NuSTAR was selected to continue mission concept studies in an extended Phase A. The Explorer budget is insufficient to support continued development of NuSTAR, IBEX, and the several other Explorer projects that have already been confirmed into Phase C/D implementation—THEMIS, AIM, and WISE. NASA chose to stop NuSTAR rather than any of the other missions that are approaching launch or are at a more advanced stage of development.

In the future, NASA will clearly identify alternate missions as such. NASA will continue to clearly inform all missions, at any stage, which continued development is subject to adequate technical progress and the availability of sufficient appropriated funds.

Q5. NASA's FY 2006 initial operating plan included $69.7 million for the Wide-field Infrared Survey Explorer (WISE) mission. Subsequent guidance provided from headquarters has reduced this funding by half. What is the rationale for cutting WISE funding? To what purpose is the money being redirected?

A5. NASA's Initial Operating Plan submitted to the Committee on February 6, 2006, included $69.7 million for WISE. On February 28, 2006, the Science Mission Directorate Associate Administrator released a letter to the WISE Principal Investigator, explicitly stating that due to funding constraints, the Project would stay in Formulation for the remainder of FY 2006, with funding limited to $30 million. NASA is currently pursuing alternatives to reinstate some or all of the FY 2006 funding of WISE in order to limit impact to the mission launch date. Any changes to WISE's budget will be reflected in a future Operating Plan adjustment.

Q6. What impact will the reduction in Radioisotope Power Systems and related technology developments have on the U.S.'s exploration and science capabilities? We have been told that, without radioisotope power systems, we won't be able to do missions beyond Jupiter and that there are no more units in production. Is this true? If this is not restarted, are we precluding any future robotic missions beyond Jupiter?

A6. While there are currently, no RTGs in production, advanced RTG *technologies* have been in development for potential use on future planetary spacecraft, to be launched in the next decade and beyond. Work on advanced RTGs has been deferred for budgetary reasons, as well as the lower number of future planetary missions expected. However, NASA expects to have sufficient radioisotope power systems to meet future needs. We are not precluding any future outer solar system missions.

In cooperation with the Department of Energy, NASA is developing a radioisotope nuclear power system for the Mars Science Laboratory. This multi-mission RTG will go into production in 2008, in order to support a 2009 launch. The rover will carry a radioisotope generator that will generate electricity from the heat of plutonium's radioactive decay. This power supply will continuously generate about 110 watts of electricity, using 4.8 kilograms of plutonium fuel. It will have a fourteen-year design life, including three years on the surface of Mars. The radioisotope-powered rover will be able to operate almost anywhere on the surface of Mars, from the polar caps to deep, dark canyons, and will safely provide full power during night and day under all types of environmental conditions. NASA has also identified potential needs for fission-based nuclear power and propulsion for space exploration. In the near-term, NASA is pursuing only a small nuclear research and technology program, focused on developing power systems for long duration stays on the lunar surface, and eventually Mars.

Options for future space nuclear power systems will be assessed along with other alternatives, such as solar power, and balanced against mission requirements and objectives.

Q7. Given the FY 2007 budget proposal and the associated run-out, how often does NASA expect to solicit proposals for Explorer, Discovery and ESSP missions? What would the optimal rate of solicitation for these programs be?

A7. The most recent Discovery Announcement of Opportunity (AO) was released in January 2006. Selections are expected by FY 2007. The next Explorer AO is scheduled for release no earlier than FY 2007. The next ESSP AO is scheduled for release no earlier than FY 2008.

The rate of solicitations for these programs is dependent on the available budget and the average mission cost. There are more than enough excellent mission concepts and qualified investigation teams to support solicitations every two years or so in each of these programs. The increased funding to support such a flight rate, however, would come at the expense of NASA's large mission flight rate or at the expense of NASA's research and analysis (R&A) programs. In the FY 2007 Budget Request, the President has proposed an appropriate mix of large missions, small missions, and R&A.

Q8a. Last year's NASA authorization bill amended NASA's mission to include tracking, cataloguing, and characterizing Near-Earth Objects (NEO), such as asteroids or comets. The bill set a goal of completing a survey of objects greater than 140m over the next 15 years.

What are you doing to implement the survey requested in the NASA authorization bill?

A8a. In 2006, SMD is participating in an Analysis of Alternatives (AoA) being conducted by the Agency, as requested by the *NASA Authorization Act of 2005* (P.L. 109–155), to determine the most effective way to conduct the survey and the budget that would be required to accomplish it. Our efforts in future years will depend on the results of this AoA.

It is important to note that the current NEO survey effort—to find at least 90 percent of all one kilometer and larger NEOs—also finds more objects less than one kilometer in size. Currently, the search teams find about 10 sub-kilometer sized asteroids for every one found larger than one kilometer. This ratio has increased over the years as the search teams have become more capable and the number of discovered large asteroids becomes a significant portion of that total actual population. As of the end of 2005, NASA-funded search teams have found 3162 near-Earth asteroids smaller than one kilometer is size. The most capable teams can find 140 meter objects when their orbits bring them within 20–25 million miles of the Earth. However, because of the constant orbital motion of these objects and other limitations in coverage of the current search systems, it would take many decades to a century to find all potentially hazardous objects with only the current capability.

Q8b. Where in NASA's budget request is the funding for the NEO survey?

A8b. In the FY 2007 President's Budget Request, the funding to continue the current one-kilometer survey is contained within the Science Mission Directorate Planetary Science R&A budget. Slightly over $4 million is allocated for this effort in FY 2007.

Q8c. Which directorate has the lead for NEO surveys?

A8c. Currently, SMD has the lead for the survey effort because of the science data we obtain from it about the constituents, populations and evolution of the Solar System.

Q8d. What is the requested budget for NEO surveys for each of the years from FY 2007 through FY 2011?

A8d. The FY 2007 President's Budget Request includes $4 million to continue the current one-kilometer survey effort. Future year budget requests will be determined with input from the AoA as at least one source of information, now that NASA has been given direction in the *NASA Authorization Act of 2005* to examine a survey effort for the smaller objects.

Q9. On March 2, NASA stated that the Dawn mission would be terminated, but on March 9, it was announced that the Associate Administrator would conduct a review of the mission termination decision. Why is NASA reviewing this decision?

A9. The NASA Associate Administrator conducted a review of the March 2 mission termination decision of the Dawn Mission at the request of NASA's Jet Propulsion Laboratory (JPL). The review assessed the Independent Assessment Team's report

and findings, the basis for NASA's original determination, as well as information provided by JPL. The review decisions were:

- The Dawn project will immediately be reinstated to a level of full funding.
- JPL will immediately re-staff the project and undertake to execute its completion.
- Science Mission Directorate (SMD) and JPL will develop a detailed re-plan, including an integrated master schedule and updated cost analysis with appropriate confidence factors.
- JPL will undertake Propulsion Power Unit 500-hour life testing as soon as possible and will report progress and outcomes to SMD within 90 days.

Q10. What steps is NASA taking to comply with section 101(d) of the NASA Authorization Act of 2005, *which requires a multi-year plan for Science? Will NASA be able to transmit the plan to Congress by the date required by the Act?*

A10. NASA plans to comply with the Congressional direction to provide a science plan by the date required by the Act. We have crafted an approach that involves the science community, including National Research Council and the NASA Advisory Council, in development and review of the draft plan. The plan will address all the specific concerns raised by the Congress in Section 101(d) of the Act. Accommodation will be made in the plan for the fact that the NRC decadal survey for Earth science will not be available from the NRC before the due date of the plan.

Q11. You stated at the hearing that once the Shuttle is retired, the NASA Science budget will not have the stress on it that currently exists—that the funding reductions to Science are a "one-time event." If that is the case, why doesn't the projected funding for Science increase in FY 2011 after the Shuttle is retired?

A11. Even though Shuttle costs are almost completely phased out by 2011, Exploration System funding is ramping up in 2011. We have carefully structured the Exploration program requirements to phase up as the Shuttle is being retired, allowing the savings from not flying the Shuttle to fund CEV, CLV and cargo launch vehicle development. This approach allows us to get a rapid start on developing Exploration systems while being able to retain an SMD growth rate of one percent per year, positioning the Agency to maintain a relative balance of science and other activities as we enter this new age of exploration.

In addition, in FY 2011 the Shuttle Program will have assets (including the orbiters) that need to be moved, disposed of or demolished, data that need to be archived, and a myriad of other tasks associated with the orderly closeout of a program of this length and magnitude. NASA has requested approximately $147 million for the Shuttle Program in FY 2011, primarily to accomplish Program Integration tasks like those described above.

Q12. NASA has recently announced a delay of the joint U.S.-Japan Global Precipitation Measurement (GPM) mission. Has there been any specific communication with Japan on this issue? If so, what concerns have the Japanese raised? Is there a point at which delays in GPM will cause Japan to withdraw support from the mission?

A12. Upon submission of the President's FY 2007 Budget Request to Congress, NASA initiated coordination with the Japanese Aerospace and Exploration Agency on the potential implications for GPM resulting from the request. The Japanese Aerospace Exploration Agency (JAXA) has encouraged NASA to minimize the delay to the mission. NASA has emphasized the importance of the GPM program and its priority within the Science Mission Directorate and has committed to continue working with JAXA as a new schedule is developed. Several discussions at various levels of management between NASA and JAXA have taken place, and these discussions are ongoing. Japan has not indicated to NASA that this slip will cause it to withdraw, nor has it indicated a point at which delays would cause it to withdraw.

Questions submitted by Representative Bart Gordon

Q1. The impact of the cuts made to the space and Earth science budget plans relative to the FY 2005 runout has been exacerbated by cost growth in a number of science projects in recent years. What are the reasons for the cost growth, and what should be done to address it?

A1. The reasons for cost growth include:

a) inherent difficulty in estimating future costs for one-of-a-kind systems, especially when undemonstrated new technologies are required
b) over-reliance on early budget estimates, before mission design is completed
c) contractor "low-balling," or at least optimism, in competitive proposals
d) scope increases (raising the performance requirements, mid-project)
e) accidental hardware damage during development
f) the withdrawal of a critical non-NASA (international or other U.S. agency) partner
g) unpredictable events, external to the project (e.g., Shuttle or launch vehicle stand-downs, parts failures experienced on other projects, contractor labor negotiations/strikes, growth in overhead rates due to delay or termination of unrelated projects, etc.)
h) Congressional direction to fund a project, and/or to avoid potential remedies such as descoping the mission, regardless of cost growth, rendering the project "untouchable."

Some of these causes are easier to address than others. NASA has taken steps to address many of them in recent years. We have:

a) reduced technology risks by funding technology demonstration projects
b) emphasized the importance of understanding the immaturity of early project estimates, and assessing the risk associated with those estimates
c) insisted on higher reserve levels during early project formulation
d) increased the number of independent project reviews
e) minimized scope increases by earlier, more thorough documentation of requirements.

There is evidence that these changes have been at least partially successful. A General Accountability Office study in the early 1990s concluded that average cost growth on NASA missions was 69 percent. At about the same time, Science missions began to show significant improvement in cost performance. Recent science missions that were launched below, at, or only slightly above baseline budget estimates include: Cassini (10/97), Chandra X-ray Observatory (7/99), WMAP (6/01), TIMED (12/01), RHESSI (2/02), Aqua (5/02), Aura (7/04), Deep Impact (12/04), and the Mars Reconnaissance Orbiter (8/05).

Unfortunately, we have seen recent cost growth in some of our larger missions in formulation. Where descoping the mission is not feasible or desirable, the impact has primarily been to delay other missions in formulation, or to defer new mission selections (i.e., Announcements of Opportunity).

Q2a. Your budget plan would limit overall Science Mission Directorate growth to one percent a year through 2011 in part due to the need to fund the Shuttle adequately until its retirement in 2010. Some have thus concluded that once the Shuttle is retired, funds will be freed up to resume a higher growth rate for the science program. However, in the 2010–11 periods, the funding requirements of the Exploration initiative go up dramatically in order to develop the heavy lift launch vehicle, the lunar lander vehicle, and other exploration-related hardware. Thus, it seems likely that any savings from retiring the Shuttle will go to pay the Exploration initiative, not to restore science cuts.

How confident are you that you will be able to increase the annual science-funding rate after 2011 if the overall NASA budget doesn't grow at a rate beyond inflation?

A2a. NASA has carefully structured the Exploration program requirements to phase up as the Shuttle is being retired. This approach allows us to get a rapid start on developing Exploration systems while being able to retain a steady funding profile for science. NASA carries out its missions with a "go-as-you-can-afford-to-pay" approach and a post-2011 funding profile below the rate of inflation would affect the rate at which NASA is able to address its full range of missions.

Q2b. What funding profile for space and Earth science is assumed in NASA's new Strategic Plan, which goes out to 2016?

A2b. NASA's budget outlook for space and Earth science assumes 1 percent per year growth from 2007–2011.

For notional planning purposes past 2011, we used a standard inflation growth rate of 2.4 percent per year.

Q3. Under the proposed budget, will NASA be investing enough in technology risk reduction and concept development for NASA and the science community to be able to adequately assess the feasibility and likely cost of future missions such as the Terrestrial Planet Finder and the Einstein probes? Should we be concerned about NASA's level of investment in new technologies?

A3. NASA is committed to continuing investments in new technologies. Technology investments enable new science investigation, enhance existing measurement or operational capability, and reduce the cost, risk and development times for missions. NASA's technology program is an aggressive, long-range program to enable the next generation of high-performance and cost-effective science missions. Our technology program includes development of new and innovative technologies from conception to demonstration in the lab, and when appropriate, flight demonstration from a sub-orbital platform (aircraft, balloon, or sounding rocket) or space (through the New Millennium Program). With the TPF and Einstein Probe missions moving further out in time, this provides us the opportunity, and time, to look at other alternative technologies that could significantly reduce the cost, risk, and schedule to accomplish the science objectives of these missions. As we look at our future investments toward our challenging missions, technology investments will be a key factor in enabling them.

Questions submitted by Representative Mark Udall

Q1. What role does your Mission Directorate play in setting the scientific goals of the human exploration program? Who has the final say in what those goals should be—the Science Mission Directorate or the Exploration Systems Mission Directorate? When will you be able to tell us what the scientific goals of the human lunar program are?

A1. The Science Mission Directorate (SMD) defines and prioritizes NASA's overall science objectives and collaborates with the Exploration Systems Mission Directorate (ESMD) to address these objectives within the lunar program as permitted by ESMD and SMD technical and budgetary constraints. A consolidated set of updated lunar science objectives should be available in mid-2007 after completion of a new National Research Council study on the subject.

Q2. Dr. Cleave indicates in her testimony that NASA will be evaluating the potential for lunar science enabled by the Exploration initiative. How do we go about ranking such exploration-enabled lunar science against alternative science projects and ensuring we are getting the best science for our money?

A2. Lunar science that could be done on the Moon was addressed in the National Research Council's (NRC) recent solar system exploration decadal survey, "New Frontiers in the Solar System: An Integrated Exploration Strategy." NASA's Science Mission Directorate has initiated a study task by the NRC's Space Studies Board that will collect, integrate, and update previous recommendations for lunar science. The approach of the study will be to begin with high priority science objectives that could be addressed by investigations on the Moon and to compare the relative technical feasibility, cost and scientific efficacy of addressing these objectives on the Moon versus other approaches. The general framework for ranking potential science opportunities enabled by human exploration activities will be to compete them in the same prioritization process as the rest of the SMD science program, since funding is expected to be drawn from the same relatively fixed overall science budget. The NASA Advisory Council's new Subcommittee on Planetary Sciences will play an important role in providing programmatic guidance on realizing these opportunities.

Q3a. NOAA's Space Environment Center (SEC) relies upon data collected from instruments on several satellite systems, including NASA's Advanced Composition Explorer (ACE) satellite.

What is the anticipated life span of the current ACE satellite?

A3a. ACE is a research satellite produced by the Explorer program of the Science Mission Directorate, and was launch in 1997 with a contract design life of three years. Since 2000, ACE has been in extended mission operations. At the current fuel usage, ACE has enough fuel to last until at least 2022. It is anticipated that ACE has sufficient electrical power generation capacity to operate until then.

Q3b. What plans does NASA have to maintain or upgrade the data stream from ACE sensors once the current ACE mission has ended?

A3b. NASA intends to maintain the ACE low-rate, real-time data stream as long as the detector systems are functional. Operational ACE data, concerning solar magnetic fields and particle streams at the L1 point, are directly transmitted to NOAA receiving equipment for analysis and display by forecasters. No upgrades to the system have been identified, and there are no plans for upgrades at this time.

Q3c. Have you been working with NOAA to transition this program from research to operations?

A3c. ACE has been used operationally by NOAA since the spacecraft was commissioned in 1997. The ACE real-time operational data is currently displayed by NOAA on the Internet at *http://www.sec.noaa.gov/ace/*. This is done, using algorithms provided by the NASA ACE experimenter team, from NOAA's Space Weather Operations (SWO) site in Boulder, Colorado. Continuity of data to the public and government users is assured assuming that the present NOAA reception and display of the processed data.

Q3d. If so, when can we expect to see a transition plan and a request for an operational system that will provide data continuity for SEC's forecasts?

A3d. Transition of responsibility for the operation of the spacecraft will be considered in the event that a future NASA Senior Review panel returns a finding that ACE has no further scientific priority for the national research effort. In the event of such a finding, it is expected that a detailed transition plan will be crafted by a subcommittee of the recently chartered NASA–NOAA Joint Working Group, assuming such a plan is appropriate for meeting NOAA's operational goals.

Questions submitted by Representative Michael M. Honda

Two weeks ago, Administrator Griffin answered a question I asked about SOFIA and testified that the budget request calls for a review of the SOFIA project because of technical concerns associated with flying a 747 with a big hole cut in the side of it. Since that time, I have learned that NASA Headquarters has been told a number of things by technical leaders on the project, including:

- *that the structural modification of the fuselage is complete*
- *that the telescope is completely installed and functional*
- *that the cavity door is locked into place and ready for closed flight testing*
- *that laminar flow over the opening is not an issue preventing SOFIA from proceeding to the flight test phase*
- *that laminar flow issues are likely to be minimal during flight test and that back-up solutions are already in place to address any anticipated problems.*

This information directly contradicts the testimony of Administrator Griffin at our last hearing, which raises a series of questions:

Q1. Can you tell me who at NASA gave the Administrator the technical and engineering information that he used in answering my question?

A1. The Science Mission Directorate is responsible for providing technical and engineering information to the Administrator.

To date, approximately 85 percent of the aircraft modification effort has been completed. Remaining work includes ground testing (e.g., vibration test), completion of the cavity door drive system, inspection of major aircraft modifications, major maintenance, as well as closeout reviews and documentation approval by both the FAA and NASA Safety and Mission Assurance. The SOFIA Program has expended approximately $438 million from inception, and at least another $200 million will be required to get through the Operational Readiness Review (ORR). Although significant progress has been made, the lost schedule cannot be recovered and the potential for additional cost growth remains.

On June 15, the NASA Program Management Council (PMC) held a technical and programmatic review of SOFIA and concluded that there were no insurmountable technical or programmatic challenges to the continued development of the program. NASA has developed a technically viable plan to proceed with the development of the SOFIA aircraft, subject to the identification of appropriate funding offsets. However, it is not yet clear whether SOFIA represents the best investment of space science funding, and NASA will need to consider funding options and sources before deciding to continue the mission.

Q2. Was that information also used in evaluating the project's merits in making a decision about FY 2007 funding levels and to hold a review intended to terminate the project?

A2. The schedule for SOFIA aircraft first flight, Operational Readiness Review, and first science flight, have all slipped substantially in the past year, due a range of technical and contractor performance issues. This status, and the associated budgetary impact and competing science priorities, led to the FY 2007 funding decision.

Q3. What NASA engineers can be produced to explain NASA's position that significant technical challenges remain? [Because the Chief Engineer on the SOFIA project believes, it is ready to proceed.]

A3. To establish the current technical, cost, schedule, and risk posture of SOFIA, and to develop options for paths forward, NASA Headquarters chartered a review to be conducted by technical and budgetary experts. On June 15, the NASA Program Management Council (PMC) held a technical and programmatic review of SOFIA and concluded that there were no insurmountable technical or programmatic challenges to the continued development of the program. NASA has developed a technically viable plan to proceed with the development of the SOFIA aircraft, subject to the identification of appropriate funding offsets. However, it is not yet clear whether SOFIA represents the best investment of space science funding, and NASA will need to consider funding options and sources before deciding to continue the mission.

Q4. It has been reported that the costs to complete SOFIA and make the observatory flyable for test evaluation are roughly equivalent to the termination costs of the program. Wouldn't it be the best use of the taxpayer's investment in SOFIA to complete the aircraft, conduct flight evaluations of the science performance of the observatory system and proceed to a productive science program?

A4. The question refers to two different costs: (1) cost to make the observatory flyable (which is equivalent to the first flight test which is essentially a door-closed flight test of the aircraft without the conduct of science observations), and (2) cost to proceed to a productive science program (which occurs after completion of the door-closed flight test program, door-open flight test program, and Operational Readiness Review (ORR)).

While cost (1) above is likely to be comparable to the termination costs for the SOFIA effort and contracts, cost (2) above is considered by NASA to be substantially greater than cost (1) above. It is for this reason, in addition to open technical and schedule concerns, that NASA chartered a review team to examine all options for pathways forward. On June 15, the NASA Program Management Council (PMC) held a technical and programmatic review of SOFIA and concluded that there were no insurmountable technical or programmatic challenges to the continued development of the program. NASA has developed a technically viable plan to proceed with the development of the SOFIA aircraft, subject to the identification of appropriate funding offsets. However, it is not yet clear whether SOFIA represents the best investment of space science funding, and NASA will need to consider funding options and sources before deciding to continue the mission.

Q5. The budget for the Innovative Partnerships Program contains no funding for the University Research, Engineering, and Technology Institutes. In 2002, NASA committed to funding these for five years—this is the fifth year, but the funding is not there. The URETIs conduct cutting edge research, train tomorrow's high tech workforce, and by their interdisciplinary nature combine the talents of researchers from schools of engineering, medicine, chemistry, and other fields to work on nano-, bio-, and information technologies. Can you explain how the decision to provide no funding for the URETIs is consistent with the emphasis on nanotechnology placed in the budget guidance memo issued by OMB and OSTP on July 8, 2005 and with the President's recently announced American Competitiveness Initiative, which has as its goals training the next generation of scientists and engineers, especially in critical interdisciplinary fields and skills?

A5. NASA currently supports four University Research Engineering and Technology Institutes (URETIs), focused on university R&D in the emerging field of nanotechnology (list attached). Each of the nanotechnology URETIs are funded under a five-year cooperative agreement, initiated in 2003, at a cost to NASA of $3M per year for each institute. The FY 2007 Budget Request for NASA did not include funding within the Innovative Partnerships Program Office budget for the fifth and final year of funding for these four URETIs. However, NASA is presently seeking to identify, within available Agency resources, approximately half of the

original final-year funding for these institutes, pending final Congressional action on NASA's budget request. We are working to achieve this partial funding arrangement in order to enable the completion of research being conducted under the URETI cooperative agreements, and to minimize disruption to the students engaged in these efforts.

Background of URETI Program

Each of the URETIs represents a collaborative cluster of Universities, with one University as the lead. These partnerships were established in 2003 with the purpose of creating a sustained dialogue with the academic community that focused on cutting-edge university research and educational experiences in areas of NASA interest. The URETI concept was intended to serve as a pathway to inspire undergraduates to consider a career in science and NASA, as well as to acquire needed enabling technologies for implementing NASA's space exploration goals. Since 2004, NASA's Exploration Systems Mission Directorate (ESMD) has provided the funding to support six URETIs: the aforementioned four institutes focused on nanotechnology-related research advancements, and two institutes engaged in R&D efforts focused on hypersonics. These include the Institute for Future Space Transportation, led by the University of Florida, and the Space Vehicle Technology Institute led by the University of Maryland.

Research Realignment in Support of Exploration Goals

When NASA defined its space exploration architecture in 2005, the Agency also realigned its research investment portfolio to ensure development of the Crew Exploration Vehicle and its launch systems by no later that 2014. NASA has reviewed its investments in long-term research in the area of nanotechnology, such as that conducted by the URETIs, and determined that this research area, while important, did not meet the criteria for critical, near-term research requirements necessary to carry out NASA's mission. Consequently, the FY 2007 Budget Request for NASA did not include funding for the four nanotechnology-focused URETIs within the Innovative Partnerships Program, which currently manages the URETIs. Full funding is maintained for these institutes through the remainder of FY 2006, the fourth year of the cooperative agreements.

NASA is currently working to achieve a partial funding arrangement, at about half the original final-year funding level, that would enable, as practicable, the completion of student research currently in progress, and an orderly ramp-down of NASA-supported work at the nanotechnology URETIs. There is no funding planned for these institutes in FY 2008. If NASA is able to identify resources, the Agency intends to provide approximately $6 million to continue URETI program support in FY 2007, or approximately $1.5 million for each of the nanotechnology institutes. We are informing the nanotechnology URETIs of our intent, and are encouraging the URETI directors to carry over remaining FY 2006 funds that may be more effectively used in FY 2007, given this level of funding. NASA's IPPO will notify the URETIs as soon as we are able to confirm our FY 2007 funding plans.

In late 2005, the Innovative Partnerships Program, previously contained within ESMD, was established as a separate NASA Headquarters Office, reporting directly to the NASA Associate Administrator. The newly created IPPO assumed management of the nanotechnology-focused element of the URETI program. Management of the two hypersonics-focused institutes is retained within ESMD. In 2006, these URETIs have been refocused towards research relevant to exploration technical risks, including vehicle thermal structures, propellant storage and delivery, re-entry aerothermodynamics, and systems analysis. Planning is underway within ESMD to continue these research teams beyond FY 2006 if continued relevance to high priority exploration needs can be shown.

Nanotechnology URETIs

Princeton University URETI

Title: Bio-Inspired Design and Processing of Multi-Functional Nano-Composites (BIMat)

Team Members: University of California-Santa Barbara, Northwestern University, University of North Carolina, Nat'l Institute for Aerospace

Technical Emphasis: To develop innovative processing technologies for the design and modeling of hierarchically structured materials capable of bio-sensing catalysis and self-healing.

Purdue University URETI

Title: Institute for Nanoelectronics and Computing (INAC)

Team Members: Yale, Northwestern, University of Florida, Cornell, University of California-San Diego, Texas A&M

Technical Emphasis: Develop fundamental knowledge and enabling technologies in materials/devices, fabrication/assembly, circuit systems and modeling for integrated nanoelectronic systems; major themes of ultradense memory, ultraperformance devices, integrated sensors, and adaptive systems.

Texas A&M University URETI

Title: Institute for Intelligent Bio-Nano Materials and Structures for Aerospace Vehicles (TiiMS)

Team Members: Rice University, Texas Southern, Prairie View A&M, University of Texas-Arlington, University of Houston

Technical Emphasis: Basic and applied research in the integration of sensing, computing, actuation and communication in smart materials and bio-materials; to enable health monitoring and fault-tolerant, adaptive control; focus on carbon nanotube technology.

University of California-Los Angeles URETI

Title: Center for Cell Mimetic Space Exploration (CMISE)

Team Members: California Institute of Technology, Arizona State, University of California-Irvine

Technical Emphasis: To mimic the complexity of the multi-scale information management (bio-informatics) of living systems, coupled with the development of new, scalable nano-technologies in sensors, actuators and energy sources.

Q6. Does it make sense to cancel the Deep Space Climate Observatory, which is a cost-effective project that has received strong support in the past, was rated as a high priority by the National Academies and plays an important role in infrastructure safety and science? How will canceling this mission impact our understanding of the Sun-Earth system and our efforts in Earth Science?

A6. With the release of the *Vision for Space Exploration* in 2004, the Space Shuttle manifest was refocused on completing assembly of the International Space Station and a possible servicing mission to the Hubble Space Telescope, thus continuing to preclude Shuttle's availability to launch DSCOVR. NASA has pursued various possibilities for access to space by expendable launch vehicle, including mission co-manifesting, but none have resulted in a fiscally viable solution. Unfortunately, the state of the budget in the context of competing priorities precludes continuation of the DSCOVR project.

Questions submitted by Representative Daniel Lipinski

Q1. What is the timeframe for beginning and completing the project review for SOFIA? What are the determining factors NASA will utilize in deciding whether or not to fund SOFIA in the FY 2007 operating plan or future budget requests?

A1. On March 15, 2006, NASA issued the Charter for the SOFIA review. The review was initiated on March 20, 2006, in Waco, TX (where the SOFIA aircraft is located). On June 15, the NASA Program Management Council (PMC) held a technical and programmatic review of SOFIA and concluded that there were no insurmountable technical or programmatic challenges to the continued development of the program. The PMC is chaired by NASA Associate Administrator Rex Geveden and comprised of NASA headquarters and center senior management. NASA has developed a technically viable plan to proceed with the development of the SOFIA aircraft, subject to the identification of appropriate funding offsets. However, it is not yet clear whether SOFIA represents the best investment of space science funding, and NASA will need to consider funding options and sources before deciding to continue the mission.

Q2. Is it standard practice to zero out all funding for a project that is "under review" before the review is actually completed? If yes, can you please identify what other projects have suffered such a fate?

A2. NASA does not have a "standard practice" in this regard. Our approach in each instance has been dependent on:

1. the reasons for the review;
2. the scope of the review;
3. the timing of the review, relative to the yearly budget process;

4. the assessed likelihood (by HQ) of the outcome of the review; and,
5. budget pressures external to the project.

Certainly, some Projects have faced potential termination, while still being supported by official budget requests. However, there is also precedent for budgets being "zeroed out" before a termination has formally occurred. Examples include Gravity Probe B (in the 1990, 1993, and 1996 President's Budget requests), and the Vegetation Canopy Lidar and Triana missions (in the 2002 President's Budget request).

Q3. Despite your assurances, the reality is that the Administration is cutting over $3 billion from the science budget relative to last year's plan. It seems to me that SOFIA is mainly on the chopping block because you need the money for other things, and SOFIA is vulnerable. If a project that is this close to completion is vulnerable, what other science projects can we expect to see on the "cut list" next year at this time?

A3. In an R&D environment, some replanning will always be necessary. Projects that are running over budget and behind schedule can be considered for cancellation even in late stages of development, but assuming a relatively stable total Science budget, we do not currently expect to propose cancellation of any additional projects next year.

Q4. Dr. Griffin testified before this committee that a "laminar flow" issue was potentially a serious problem for SOFIA. That issue apparently was not raised in any of the most recent technical reviews of the project, though you did mention in your testimony before the Committee that there is a disagreement at NASA regarding the details of this possible problem. What was the basis of Dr. Griffin's statement and your description? Can you please provide documents to support your claims?

A4. On June 15, the NASA Program Management Council (PMC) held a technical and programmatic review of SOFIA and concluded that there were no insurmountable technical or programmatic challenges to the continued development of the program. The PMC is chaired by NASA Associate Administrator Rex Geveden and comprised of NASA Headquarters and center senior management. NASA has developed a technically viable plan to proceed with the development of the SOFIA aircraft, subject to the identification of appropriate funding offsets. However, it is not yet clear whether SOFIA represents the best investment of space science funding, and NASA will need to consider funding options and sources before deciding to continue the mission.

To date, approximately 85 percent of the aircraft modification effort has been completed. Remaining work includes ground testing (e.g., vibration test), completion of the cavity door drive system, inspection of major aircraft modifications, major maintenance, as well as closeout reviews and documentation approval by both the FAA and NASA Safety and Mission Assurance. The SOFIA Program has expended approximately $485 million from inception through the end of March 2006, and at least another $250–300 million will be required to get through the Operational Readiness Review (ORR).

Q5. Dr. Cleave, Dr. Griffin and others have mentioned "technical problems" that led to the NASA decision to zero out funding for SOFIA. Can you identify the specific technical or other concerns that led to this decision, as well as how those concerns were identified—was there a prior review that raised a red flag? If so, could you please provide a copy of it to us?

A5. The basis for formulating the FY 2007 Budget Request includes technical, schedule, and cost considerations. The schedule for SOFIA aircraft first flight, Operational Readiness Review, and first science flight, had all slipped substantially in the past year, due a range of technical and contractor performance issues. In addition, the specific area of the cavity door drive system and associated door brackets misplacement, are current technical matters in work. In addition, recent technical problems with the aircraft heavy maintenance D–Check, including damage to the aircraft, and sign-off of work that was not completed, were also factors. This status, and the associated budgetary impact and competing science priorities, led to the FY 2007 funding decision.

Q6. Do you believe that the cancellation of this and other scientific programs sends the wrong message to undergraduate and graduate students—to study other fields rather than science? What impact will the cancellation of SOFIA and other science programs have on the future NASA workforce and how does it tie into the President's American Competitiveness Initiative? How does NASA expect

to increase the number of young people entering the scientific fields of study, if the Administration keeps cutting the funding of important scientific programs?

A6. The NASA Science Mission Directorate still has over 50 missions in operation and over 40 missions in development with launch dates planned before 2012—plus missions like JWST in the next decade. Only a small percentage of SMD projects have been slowed down or canceled. NASA is maintaining a vibrant space science program that will still attract the best and brightest young scientists and engineers.

Q7. Given that the SOFIA is a program conducted in collaboration with the German Aerospace Center, what impact will the zeroing-out of this program have on the U.S./German partnership? Have you talked to our German partners about the lack of funding and what has been their reaction?

A7. NASA has been in regular contact with the German Aerospace Center (DLR) regarding the status of the SOFIA program, including a number of direct discussions between the NASA Deputy Administrator and the DLR Chairman. In addition, NASA invited DLR representatives to participate as ex-officio members of the review team which evaluated options for the program. The DLR members were thoroughly involved in all of the team's activities, and made a valuable contribution to its review of the program. Science Mission Directorate officials have also held regular telecons with their DLR counterparts to ensure that they were fully engaged in this process. DLR leaders have been extremely supportive during these discussions, and have been encouraged by the conclusion of NASA's recent technical and programmatic review that could potentially lead to the continuation of the mission. NASA has informed DLR that continuation of the mission would be subject to the identification of appropriate funding offsets.

Questions submitted by Representative Eddie Bernice Johnson

Q1. How did NASA determine the relative priority of each of its science programs in order to allocate the limited available funding among them?

A1. The funding for each science division reflects the re-balancing of the science portfolio begun last year with the Amendment to the FY 2006 Budget Request. Each division determined the proposed mix of large missions, small missions, and research, using community input from the decadal surveys and other National Research Council and Space Studies Board reports to guide this process.

We intend to discuss this issue further with the NASA Advisory Council (NAC), with representatives of the science community and the Space Studies Board of the National Academy of Sciences, and will seek their advice to ensure that we maintain an appropriate mix within each Science Mission Directorate (SMD) Division between R&A, small-, medium-, and large-class missions. The Space Studies Board met March 6–8, 2006, and their report *"An Assessment of Balance in NASA's Science Programs"* has been received and is currently under review. The science subcommittees of the NAC met May 3–4, and the chairs of each subcommittee sent recommendation letters to the Science Committee Chair. These subcommittee recommendations were discussed at the NAC meeting on May 18 at the Jet Propulsion Laboratory, and NASA anticipates receiving formal recommendations for SMD within the next few weeks. Should changes in the mix of R&A and mission investment be determined to be appropriate, we may pursue that course of action, potentially via an adjustment in NASA's FY 2006 Operating Plan and NASA's initial FY 2007 Operating Plan.

Q2. What impact will the empty promise of greater funding have on NASA's Science Mission Directorate's ability to plan long-term research initiatives?

A2. The NASA Science Mission Directorate still has over 50 missions in operation and over 40 missions in development with launch dates planned before 2012—plus exciting missions like JWST in the next decade. Only a small percentage of NASA projects have been slowed down or canceled. NASA is maintaining a vibrant Earth and space science program that will still attract the best and brightest young scientists and engineers.

Questions submitted by Representative Brian Baird

Q1. In 2004, NASA, along with NOAA and the USGS, requested that the National Academies of Science (NAS) "generate consensus recommendations from the Earth and environmental science and applications community regarding science priorities [for Earth observations from space]." In the winter of 2005, NAS re-

leased a preliminary report which asked that NASA "launch the Global Precipitation Measurement mission (GPM) without further delays." In response, in spring 2005 NASA advanced the launch date by one year. However, the FY 2007 NASA budget request would reverse this decision, and would delay the launch by at least two years, potentially jeopardizing the international partnership that is the basis of GPM and particularly Japanese involvement—critical because key instruments on the mother spacecraft are to be provided by JAXA, the Japanese space agency. How did NASA come to the decision to delay this mission, and do they intend to follow the NAS recommendations regarding Earth Science once the entire report is released in Fall, 2006?

A1. The Global Precipitation Measurement (GPM) mission is currently in formulation phase within the Earth Science Division of the Science Mission Directorate. The NASA Administrator has stated that formulating the NASA FY 2007 budget request required discipline and difficult decisions. As a result, the Science Mission Directorate rate of growth over the next four years was reduced. These reductions were focused on missions that had not yet been through a confirmation review and thus would be less severely impacted. Unfortunately, this resulted in delaying the launch of GPM.

In responding to this changed budget situation, the Science Mission Directorate1s overall strategy is to develop an executable program based on science priorities provided by the community via National Academy of Sciences studies, including those addressing Earth Science. We look forward to receiving the final version of the NRC decadal survey in Earth Science later this year to aid in this process.

ANSWERS TO POST-HEARING QUESTIONS

Submitted to Joseph H. Taylor, Jr., Co-Chairman, National Academy of Sciences Decadal Survey for Astrophysics; James S. McDonnell Distinguished University Professor of Physics, Princeton University

These questions were submitted to the witness, but were not responded to by the time of publication.

Questions submitted by Chairman Sherwood L. Boehlert

Q1. Should the community change the Decadal Survey process so that the Survey is done for several different, specific budget scenarios? Should a process be established for updating the Surveys if significant new budgetary or scientific information comes in during the 10-year period covered by a Survey?

Q2. You mention the issue of cost growth in your testimony, saying you "believe the correct procedure is for NASA to set up a task force to work with centers and contractors to improve the reliability of the cost, schedule and technology risk estimates, including proper contingencies, for each of the selected missions." Would you care to elaborate? How does this differ from today's program reviews?

Q3. In your written testimony you mention the exciting new area of "dark energy." Has NASA consulted with the astrophysics community regarding a preferred mission for the study of "dark energy"? Should NASA's priorities be reordered to give greater emphasis to the study of "dark energy"?

Questions submitted by Representative Bart Gordon

Q1. In her testimony, Dr. Cleave stated that the rationale for the cuts to the Research and Analysis (R&A) funding was "directly related to the slowing rate of growth of Science Mission Directorate programs" and the need to achieve a better balance.

- *Do you agree with that rationale?*
- *What is an appropriate level of R&A funding and why?*

Q2. You have expressed concern over the impact of the proposed cuts to NASA's space and Earth science budget plans. If you were the NASA Administrator, what approach would you take to prioritize NASA's planned activities given the current constrained budgetary outlook for NASA, and why?

Q3. The impact of the cuts made to the space and Earth science budget plans relative to the FY05 runout has been exacerbated by cost growth in a number of science projects in recent years. What are the reasons for the cost growth, and what should be done to address it?

Q4. Under the proposed budget, will NASA be investing enough in technology risk reduction and concept development for NASA and the science community to be able to adequately assess the feasibility and likely cost of future missions such as the Terrestrial Planet Finder and the Einstein probes? Should we be concerned about NASA's level of investment in new technologies?

Questions submitted by Representative Mark Udall

Q1. You have expressed your concern about the health of the Explorer program under this budget plan. What would it take to restore the Explorer program to health, and what would a healthy program look like?

Q2. You discuss the need for a range of mission sizes. In developing the recommendations in your decadal survey, what criteria governed the balance you sought between small, medium, and large missions?

Q3. Dr. Cleave indicates in her testimony that NASA will be evaluating the potential for lunar science enabled by the Exploration initiative.

- How do we go about ranking such exploration-enabled lunar science against alternative science projects and ensuring we are getting the best science for our money?

Question submitted by Representative Eddie Bernice Johnson

Q1. What impact will the empty promise of greater funding have on NASA's Science Mission Directorate's ability to plan long-term research initiatives?

ANSWERS TO POST-HEARING QUESTIONS

Responses by Fran Bagenal, Member, National Academy of Sciences Decadal Survey for Sun-Earth Connections; Professor, Astrophysical and Planetary Sciences, Laboratory for Atmospheric and Space Physics, University of Colorado

Questions submitted by Chairman Sherwood L. Boehlert

Q1. Should the community change the Decadal Survey process so that the Survey is done for several different, specific budget scenarios? Should a process be established for updating the Surveys if significant new budgetary or scientific information comes in during the 10-year period covered by a Survey?

A1. I believe each Decadal Survey should be done only once per decade. It is very rare that space science moves so rapidly that the scientific priorities change within a decade. On the other hand, it is often the case that the *implementation* of these scientific priorities needs to change to accommodate either changes in mission costs or budget profiles—usually both. In reality, it is not possible to completely de-couple the scientific priorities of a Decadal Survey from the practicalities of implementation. Decadal Surveys are built from mission concepts that aim to achieve specific scientific objectives. Without accurate estimates of the costs of implementing such missions any Decadal Survey lacks a realistic foundation. Thus, the primary basis of a useful Decadal Survey needs to be accurate costing of mission concepts that allows a prioritization of these missions—and the science that they are expected to achieve. Should NASA budget profiles change within the 10-year period covered by a Survey then issues of implementation of specific missions needs to be discussed between NASA and the scientific community through an advisory structure such as the subcommittees of the NASA Advisory Council (NAC) corresponding to the Divisions of the Science Mission Directorate.

Questions submitted by Representative Bart Gordon

Q1. In her testimony, Dr. Cleave stated that the rationale for the cuts to the Research and Analysis (R&A) funding was "directly related to the slowing rate of growth of Science Mission Directorate programs" and the need to achieve a better balance.

Q1a. Do you agree with that rationale?

A1a. No, I do not agree with this rationale. While R&A does indeed support missions, it also does much more. Under R&A many small, innovative projects carry out a wide variety of objectives from compiling many different data sets from multiple missions to development of theoretical models for comparison with existing or future mission data to proto-typing new instrument concepts.

Q1b. What is an appropriate level of R&A funding and why?

A1b. There is not quick answer to this question. Each scientific program of R&A within the Science Mission Directorate has an (relatively slow) evolution with time in response to scientific growth in a particular sub-field of research. The Program Managers have detailed knowledge of how these fields are changing and the quantity and quality of responses to Announcements of Opportunity to propose to these programs. Adjustment of the level of funding of different R&A programs and the overall level relative to mission funding lines should be made by the Division Directors in consultation with the appropriate advisory subcommittee.

Q2. You have expressed concern over the impact of the proposed cuts to NASA's space and Earth science budget plans. If you were the NASA Administrator, what approach would you take to prioritize NASA's planned activities given the current constrained budgetary outlook for NASA, and why?

A2. The most pressing issue to address is the alarming way that missions seem to be under-costed to start with as well as how mission costs overrun initial budgets. The scientific community—through the division subcommittees of the NAC—needs to work with NASA to first address this issue—as well as develop realistic implementation plans for completing missions prioritized by the Decadal Surveys.

Q3. The impact of the cuts made to the space and Earth science budget plans relative to the FY05 runout has been exacerbated by cost growth in a number of science projects in recent years. What are the reasons for the cost growth, and what should be done to address it?

A3. The point made above is worthy of repetition: The most pressing issue to address is the alarming way that missions seem to be under-costed to start with as well as how mission costs overrun initial budgets. The scientific community—through the division subcommittees of the NAC—needs to work with NASA to first address this issue—as well as develop realistic implementation plans for completing missions prioritized by the Decadal Surveys.

There are probably several causes of mission cost growth: major changes in NASA's accounting systems (i.e., Full Cost Accounting); the sharp rise in launch costs; delays that lead to additional costs (e.g., "standing armies" of engineers/managers/scientists, storage/maintenance/rebuilding of instrumentation, inflation); initial under-costing of missions; requirement creep; increased documentation to minimize perceived risk. The NASA advisory bodies cannot solve these issues alone. The solution lies in bringing together the expertise of experienced mission managers, the administration of the NASA centers and the PIs who have seen successful missions to completion within budget targets. For example, there are lessons to be learned for both NASA administration and the scientific community from the recent NRC report on PI-led missions. There must also be rigorous, on-going review of center-led (non-PI-led or flagship) missions that assesses whether these missions are on schedule and on budget. NASA administration must be willing to find more cost-effective alternatives or cancel missions that run over budget and the scientific community must accept such possibilities.

Q4. Under the proposed budget, will NASA be investing enough in technology risk reduction and concept development for NASA and the science community to be able to adequately assess the feasibility and likely cost of future missions such as the Terrestrial Planet Finder and the Einstein probes? Should we be concerned about NASA's level of investment in new technologies?

A4. More important than the total amount of funds being invested in technology is whether the funds are being targeted at the most appropriate development of technology. This issue is closely coupled to accurate costing of missions—it is key that appropriate level of funding be budgeted for technology development. Furthermore, it is critical that decision points be identified during the mission planning/development at which the readiness of such technologies be carefully evaluated so that an informed decision can be made about whether a mission should proceed.

Questions submitted by Representative Mark Udall

Q1. You have expressed your concern about the health of the Explorer program under this budget plan. What would it take to restore the Explorer program to health, and what would a healthy program look like?

A1. A healthy Explorer program would produce a launch every 12–18 months. This entails an approximately annual Announcement of Opportunity to propose, alternating between small (SMEX) and medium (MIDEX) class missions, which would produce a competitive selection of a handful of concepts for feasibility study. Review of such technical/management/cost feasibility studies would lead to selection of a mission for flight. In order to allow rapid (<5-year) progress from mission concept to launch, to take advantage of advances in technology and to provide the opportunity to give junior scientists and engineers valuable flight experience, it is necessary that the Explorer program be recognized to entail higher risk that flagship-class, center-led missions. This means that the burden of bureaucratic process be limited to that appropriate for good practice of such small-scale missions (guidance for which can be provided by the pool of experienced Principal Investigators and Mission Managers of Explorer missions that their achieved scientific goals on budget and on schedule).

Q2. Dr. Cleave indicates in her testimony that NASA will be evaluating the potential for lunar science enabled by the Exploration initiative.

How do we go about ranking such exploration-enabled lunar science against alternative science projects and ensuring we are getting the best science for our money?

A2. Historically, many planetary and space scientists cut their professional teeth on lunar science. Many of the current scientific leaders worked on Apollo data. Understanding of basic planetary and space physics processes were developed in the Apollo era. Many of these scientists have moved (via robotic spacecraft) out into the solar system to apply techniques gleaned at the Moon to other places and to learn about planetary processes through comparison with the lunar case. Thus, the Moon has taught us valuable lessons but explorations since Apollo have shown us a much big-

ger view of the origin and evolution of our solar system and that the Moon is just one specific, isolated and rather idiosyncratic example of planetary bodies. Potential return of humans to the Moon provides an important opportunity for detailed study of outstanding issues of lunar science but it will be crucial that the larger scientific community of planetary scientists be involved in evaluating the cost-benefit of extensive lunar exploration for furthering our understanding of key scientific issues. While we, as terrestrial beings, hold the Moon particularly dear as our companion planetary body, further knowledge of our neighbor does not necessarily help us answer the priority scientific questions about the evolution of our solar system and the origins of life therein.

It should also be noted that to enable humans to safely return to the Moon we need accurate and reliable predictions of the charged particle and radiation conditions—space weather—that astronauts will experience. This entails better understanding of how conditions between the Sun, Earth and Moon are affected by solar activity—the fundamentals of Heliophysics research.

Question submitted by Representative Eddie Bernice Johnson

Q1. What impact will the empty promise of greater funding have on NASA's Science Mission Directorate's ability to plan long-term research initiatives?

A1. I believe that the current focus of NASA's Science Mission Directorate should be to urgently address the issue of controlling escalating costs of missions. It is impossible to make long-term plans if the estimates of mission costs are constantly growing. The scientific community—through the division subcommittees of the NAC—needs to work with NASA to first address this issue—as well as develop realistic implementation plans for completing missions prioritized by the Decadal Surveys. Currently, about one-third of NASA's budget is allocated towards the Science Mission Directorate—a substantial sum that should allow a healthy science program. The scientific community needs to work with the NASA administration to make sure the taxpayers' money returns the best science.

Questions submitted by Representative Michael M. Honda

Q1. Does it make sense to cancel the Deep Space Climate Observatory, which is a cost-effective project that has received strong support in the past, was rated as a high priority by the National Academies and plays an important role in infrastructure safety and science? How will canceling this mission impact our understanding of the Sun-Earth system and our efforts in Earth Science?

A1. A recent NRC report highly rated the science achievable by the Deep Space Climate Observatory. The issue is of implementation. Competition tends to reveal strengths and weaknesses of different approaches to implementing a mission. The key concern is whether, after many years of delay, the most cost-effective approach is to continue with the original mission vs. refurbishing the spacecraft with up-to-date technology. Peer review is the best (and affordable) way to evaluate whether a better job could be done at the same cost.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Wesley T. Huntress, Jr., Member, National Academy of Sciences Decadal Survey for Solar System Exploration; Director, Geophysical Laboratory, Carnegie Institution of Washington

Questions submitted by Chairman Sherwood L. Boehlert

Q1. Should the community change the Decadal Survey process so that the Survey is done for several different, specific budget scenarios? Should a process be established for updating the Surveys if significant new budgetary or scientific information comes in during the 10-year period covered by a Survey?

A1. The Decadal Survey is more about science than it is about missions, and the science goals are more enduring than the mission implementations. A balance of missions between low, medium and large is identified in each Decadal Survey with priorities in each class. This allows NASA to choose the mix it can afford in any budget year. I do not think that any Decadal should assume a set of budget scenarios but rather provide the prioritized lists of various cost classes as the means of responding to changing fiscal conditions. The most serious problem arises when the large class missions at the top of the flagship priority list can't be accommodated because of cost increases or budget decreases. At that point, a supplementary update report can be prepared by the NRC to address this issue.

Q2. You note in your testimony that NASA will not be launching a flagship mission (such as a mission to Europa) for planetary sciences this decade, the first time that has happened in many decades. You also say in your testimony that "the momentum of current mission development will carry [the solar system exploration program] for about two years, and then the bottom begins to fall." Can you elaborate on why flagship missions are important? Why would learning about Europa a couple of years later be detrimental?

A2. Flagship missions are important for two reasons. First, they allow a comprehensive study of the destination on a single mission when simultaneous measurements by multiple instruments are required. Second, some high value missions are simply very expensive, such as a Mars Sample Return or missions to Europa, Titan and most other outer planet objectives. While it is always easy to say that we can wait a few more years to learn what we want to know about Europa, how long *should* we wait to find out about Europa's subsurface oceans? And without some continuous technological work on this style of mission, our ability ultimately to mount such a mission will wither. Remember that we can no longer build a Saturn V. The same holds true for spacecraft as for launch vehicles.

Q3. NASA has stated that it reduced the number of missions to Mars by eliminating human precursor missions, while maintaining the high-priority science missions. Given the available funding, did NASA remove the correct missions to maintain the science and research activities for Mars?

A3. The human precursor line of Mars missions has been eliminated because Mars human missions are two or three decades into the future. However, the science mission line has been reduced as well. Essentially, instead of being able to send two medium-class missions to Mars, as in the case of the two rovers launched in 2003, NASA will only be able to alternate between one medium-class mission in one launch opportunity and a small mission in the following launch opportunity. There will be only one, instead of two, Mars Surface Laboratory rovers launched in 2009, thereby increasing mission risk and reducing the science return. Other medium-class high priority missions such as an astrobiology rover mission are deferred, and no large missions can be flown at all, such as the Mars Sample Return mission the Decadal Survey identified as the highest priority Mars mission in the next decade.

Questions submitted by Representative Bart Gordon

Q1. In her testimony, Dr. Cleave stated that the rationale for the cuts to the Research and Analysis (R&A) funding was "directly related to the slowing rate of growth of Science Mission Directorate programs" and the need to achieve a better balance.

- *Do you agree with that rationale?*
- *What is an appropriate level of R&A funding and why?*

A1. No, I do not agree with Dr. Cleave's rationale. Dr. Cleave seems to believe that the best strategy is to cut everything proportionately, failing to recognize those programs fundamental to the future of the enterprise as distinguished from those that are more discretionary. The science community is space science's 'boots on the ground' and the wellspring of NASA's flight missions. The R&A program is fundamental and mandatory to maintaining this Nation's capability in space science. The mandatory programs in space science are first the R&A, data analysis and technology programs that form the base rock for the flight programs. Also mandatory are the small flight mission lines such as Discovery and Explorers that in the absence of any other missions provide for a continuous and stable flight rate. Next are medium-class missions and finally flagships.

There is no magic formula to rationally calculate the fraction of the program that should be dedicated to R&A. The level is determined by practice, essentially provided by the experience built up over four decades to establish the current necessary resource level. This level has been hard enough to maintain over the years given OMB's constant misplaced attitude that R&A is an entitlement program, so that R&A generally declines to inflation unless a new program like Astrobiology is brought on. In my view, R&A should never be cut at all. It will leak away to inflation in any case without proactive and constant support by the Agency.

Q2. You have expressed concern over the impact of the proposed cuts to NASA's space and Earth science budget plans. If you were the NASA Administrator, what approach would you take to prioritize NASA's planned activities given the current constrained budgetary outlook for NASA, and why?

A2. As I indicated during questioning, within the Earth and space sciences, the priorities for maintaining a healthy science enterprise are: 1. R&A and mission data analysis, 2. Technology development for future missions, 3. Low-cost, high-flight rate mission lines such as Discovery and Explorers, 4. Medium cost missions and mission lines such as New Frontiers, and finally 5. Flagship missions. I would seek a balance amongst all these elements within these priorities. This is not what is being done in Earth and space sciences in response to the FY07 budget reductions.

If I were the NASA Administrator under the current constrained budgetary outlook, I would freeze Earth and space sciences at the 32 percent level and tie its future budgets to this same percentage (not set it on a decline as Dr. Griffin has done), set human space flight at its current percentage as well and 'go as you can afford to pay' rather than continue to damage other parts of the Agency. If this would mean a longer hiatus between Shuttle termination and CEV availability then so be it. We can't afford it otherwise and certainly not by damaging this nation's future in science, technology and aeronautics. If it were not for the Administration insisting on completing the ISS, I would tell the international partners that the Shuttle is not worth the risk and cost, and work with them to create a new plan on how to proceed together to get beyond the ISS. I have no confidence the Shuttle can deliver 16 flights over the next four years; it is too old, too dangerous, and too beset with operational problems.

Q3. The impact of the cuts made to the space and Earth science budget plans relative to the FY05 runout has been exacerbated by cost growth in a number of science projects in recent years. What are the reasons for the cost growth, and what should be done to address it?

A3. The Earth and space science enterprise certainly does have some of its own house to get in order. I can answer authoritatively only for the planetary missions. Cost growth has been due largely to starting projects before the technologies have matured sufficiently, or to technologies being lost during development due to industrial sell-offs and key skills being dispersed. These issues can generally be handled by understanding which issues are beyond the project's control and which are not. In the former case, for the smaller missions such as Dawn that exist within program lines like Discovery, it was my practice to provide an extension to solve problems outside the project's control and delay the next mission to be started. Lately however, the practice seems to be hard-line cancellation without regard to circumstances or sunk cost. As for the monumental increase in JWST costs and some other missions, I have no insight.

Q4. In your testimony, you state that you are an advocate for "the scientific exploration of space-using both robotic and human elements."

- *Do you believe that science has been properly integrated into NASA's exploration program? If not, why not?*
- *What would you recommend be done to ensure that science and exploration are appropriately integrated?*

- *In the past, you have talked about the desirability of a step-by-step approach to human exploration, wherein the destinations and exploration approach are determined by the* scientific objectives *being sought. Why do you think that is the right approach to take, and is that what NASA is doing in its exploration initiative?*

A4. Science has not been integrated into NASA's human exploration program at all. Science is of course well integrated into NASA's robotic exploration program. The naming of NASA's Exploration Division perpetuates a false notion than only humans explore. NASA has been concentrating on HOW to go back to the Moon, not on WHY we should do it other than the President said so (ironically, the Vision document gives good answers to WHY), nor is NASA working enough on WHAT we will do when we get there. That's what scientists do. Scientists should be determining WHAT we should do on the Moon so that the engineers can figure out HOW. The cart has been put before the horse. This is exactly how the ISS got into trouble as a 'laboratory in space'. Ultimately the ISS became no such thing.

NASA's ESMD needs to have scientists on their staff that can help and advise, conduct studies on the science content for human and robotic exploration together, and work across the boundary with SMD. There are no scientists in ESMD at the moment. SMD and ESMD together should be marshalling the science community to determine what should, and should not, be done by human explorers on the Moon and beyond. They have done almost nothing so far.

ESMD needs to consider science as a partner, instead of a nuisance, and engage the science community waiting to be asked to participate. There are already pre-existing and recent studies done both within and without NASA that can provide a head start.

I do believe that the goals should determine the destinations, because ultimately it is what we do, not how we do it or where, that will provide the benefits to humanity. But the budget for the new exploration initiative in my opinion is barely sufficient to replace our Earth-to-orbit infrastructure—a CEV, a launcher for the CEV and a large cargo launcher. I don't think there will be enough in the runout of this budget to begin hardware development for the Moon, much less anything beyond. So it is no surprise that NASA focuses entirely on the Moon and develops an architecture that is more Apollo-like and lunar-specific, and perhaps not as extensible to other destinations. As I said at the hearing, this is Apollo on food stamps, not the highway to the solar system so well articulated in the President's 2004 Vision. The 2004 Vision is so seriously under-funded now as to constitute no more than Earth-to-orbit infrastructure replacement.

Q5. Under the proposed budget, will NASA be investing enough in technology risk reduction and concept development for NASA and the science community to be able to adequately assess the feasibility and likely cost of future missions such as the Terrestrial Planet Finder and the Einstein probes? Should we be concerned about NASA's level of investment in new technologies?

A5. We should be very concerned that NASA is not investing enough in technology and concept development to maintain its ability to conduct future missions such as TPF and Einstein probes. These are technologically challenging missions requiring highly specialized scientists and technologists. The planned terminations and reductions in funding will force these people to find other more stable opportunities, and their skills and technology lost to NASA. You can't just turn off scientists and technologists and expect to recover them after a time. Between losing these highly skilled people, and losing the brightest young people who will now see not much of a future in NASA, we will have mortgaged our ability to conduct such world-class missions in the future.

Questions submitted by Representative Mark Udall

Q1. You discuss the need for a range of mission sizes. In developing the recommendations in your decadal survey, what criteria governed the balance you sought between small, medium, and large missions?

A1. In the Solar System Decadal Report, the number of flights per decade in each mission class was determined by examining the history of flight rates in past decades, mixed with assuming a top-line budget for the coming decade. In the 2003 decadal this was a budget that increased with the projections for the top line of the Agency, generally tracking inflation. In other words, no growth rate was assumed larger than the Agency itself. The result was one flagship per decade, three medium-class New Frontiers missions per decade, and one small-class Discovery mission every eighteen months. The Mars program assumptions were the same, with

one to two medium-class launches per opportunity (every 26 months) and one small Scout launch every other opportunity.

Q2. In your testimony you state that: "The bottom line is that the future of our nation's solar system exploration enterprise has been mortgaged. The momentum of current mission development will carry it for about two years, and then the bottom begins to fall out."

- *That is strong language. Would you please elaborate on what you mean?*

A2. NASA has terminated or deferred flight missions in development without maintaining our ultimate ability to conduct them in the future. This is because the Agency has reduced, and some cases terminated, funding for technology and concept development that would allow the continuity required to revive these missions at a later date. Earth and space science flight missions, particularly the flagships, are technologically challenging, requiring highly specialized scientists and technologists to work on them. Precipitous reductions and termination of funding will force these skilled people to find other more stable opportunities. As a result, their skills and technology will be lost to NASA. You can't just turn off scientists and technologists and expect to recover them after a time. Between losing these highly skilled people, and losing the brightest young people who will now see not much of a future in NASA, we will have mortgaged our ability to conduct such world-class missions in the future.

Q3. In her testimony, Dr. Cleave lists the reasons why funding for astrobiology was cut by 50 percent, including "the lower flight rate for Mars missions, plus the recognition that human exploration missions to Mars are further in the future than previously assumed," *as well as the previous growth in astrobiology funding.*

- *You were at NASA when the astrobiology program was established. Was astrobiology meant to be tied exclusively to Mars exploration?*
- *What was NASA trying to accomplish with the astrobiology program, and what impact would the proposed cuts have on the ability to achieve those goals?*
- *How popular has astrobiology been with the emerging crop of young scientists, and what will happen to them and the field if the proposed cuts are adopted?*

A3. The astrobiology program was not established exclusively for Mars. Dr. Cleave does not understand her own program. The astrobiology research program was started as the research element of the Origins Program, the goals of which are to search for the origin of life on Earth, and to search for evidence of past or present life in our own solar system and in the universe beyond. The Origins program included technology development to enable flight missions to search for planets around other stars, such as SIM, and ultimately characterize Earth-like planets around other stars, such as TPF. It also increased the number of missions to Mars to search the red planet for evidence of water and life, and included technology and concept development for a mission to Europa to characterize its internal ocean as a potential abode for life. A survey of what has been cut, canceled and deferred from space science in this FY07 budget looks very much like everything in the Origins Program.

The astrobiology program is tied to understanding the origin and evolution of life on Earth and how we might go about looking for it beyond our own planet. It was not meant to be Mars exclusive, nor is it. Much of the research is actually done on understanding basic life processes in microbes living in extreme conditions here on Earth as potential examples of what we might find 'out there', and in establishing where we might look for signs of past or present life on any other planet including those around other stars. It also funds the development and testing of protocols and instruments to search for evidence of life on other planets. A lot of these developments have significant medical applications. The proposed cuts would short-circuit much of this work, crippling the ability of future missions to conduct any search for evidence of past or present life on Mars or Europa, and curtailing understanding of basic life processes in cells important not just for understanding the origin and evolution of life on Earth, but for medical application as well.

The astrobiology program was intended to attract biologists back to NASA after Viking in 1976 found no sign life on Mars. It was intended to create a new interdisciplinary science by putting biologists together with chemists, physicists, astronomers and geologists to address some of the most fundamental questions regarding life in the universe, and to search in the seams between the traditional science disciplines where new discoveries were hiding. It has succeeded enormously well. It is

the most vibrant new field of science in NASA, and has the envy of other science agencies in government. It has attracted an enormous number of bright, young researchers who are contributing heavily to new discoveries. Astrobiology has rejuvenated space science in NASA. The proposed cutback will strand a thousand of our brightest young scientists and divert them from promising careers just when our nation needs to cultivate science and engineering careers for its young people.

Q4. Dr. Cleave indicates in her testimony that NASA will be evaluating the potential for lunar science enabled by the Exploration initiative.

- *How do we go about ranking such exploration-enabled lunar science against alternative science projects and ensuring we are getting the best science for our money?*

A4. The best approach is the one space science has been using for four decades. First engage the National Academy of Science to provide the equivalent of a Decadal report for lunar science; to define the strategic goals for combined human-robotic exploration of the Moon in the next 10–20 years. NASA should fund the requisite mission concepts for the Academy study and utilize the NASA Advisory Council's subcommittee structure to devise a roadmap to achieve the goals that result from the study.

Question submitted by Representative Eddie Bernice Johnson

Q1. What impact will the empty promise of greater funding have on NASA's Science Mission Directorate's ability to plan long-term research initiatives?

A1. I am not sure whose 'empty promise' is meant, but let me assume that it is NASA's promise that after Shuttle retirement, the science funding lost in this budget will be returned. I don't believe this for a moment. This FY07 budget sets a new pattern for NASA spending and it won't be altered once human space flight is 'fixed'. No one who made that promise will be around five years from now, and human space flight will find its own reasons not to return the favor.

The Science Mission Directorate should assume that it will not get any of this money back, and plan accordingly. SMD will need to wage an annual battle to prevent its budget from eroding further into human space flight. SMD should battle to maintain at least its current 32 percent share of the NASA budget, and to increase it to the extent that it can.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Berrien Moore III, Co-Chairman, National Academy of Sciences Decadal Survey for Earth Sciences; Director, University Distinguished Professor, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire

Questions submitted by Chairman Sherwood L. Boehlert

Q1a. Should the community change the Decadal Survey process so that the Survey is done for several different, specific budget scenarios?

A1a. I believe so. This is what the Earth Sciences Decadal Survey will do. The one difficulty is that we must still be modestly optimistic about the budget. Were we to "accept" the NASA Earth Science budget, then there would be almost no need for a Decadal Survey, at least in this decade.

Q1b. Should a process be established for updating the Surveys if significant new budgetary or scientific information comes in during the 10-year period covered by a Survey?

A1. Yes, if the budget environment is significantly changed either by cost growth or budget reductions; however, this should be a rare event.

Questions submitted by Representative Bart Gordon

Q1. In her testimony, Dr. Cleave stated that the rationale for the cuts to the Research and Analysis (R&A) funding was "directly related to the slowing rate of growth of Science Mission Directorate programs" and the need to achieve a better balance.

Q1a. Do you agree with that rationale?

A1a. No, I strongly disagree. As the number of new missions decline and hence funding for data analysis associated with the new mission declines, then it is ever more important to maintain a healthy Research and Analysis program to keep the flow of new ideas strong and to continue to attract new young people to Earth and Space science. This means a tip in the balance toward R&A rather than away from R&A. NASA is moving in exactly the wrong direction.

Q1b. What is an appropriate level of R&A funding and why?

A1b. This is a very difficult question, and I am not sure I have an adequate answer. I know when it seems adequate and when it appears inadequate. My "test" involves an informal synthesis of new opportunities, rejection rates, and community morale and excitement. When the rejection rates reach 85 percent to 90 percent, then there is likely to be trouble. We were already on the edge of trouble with the FY05 budget and the FY06 operations changes. The FY07 budget is major trouble.

Q2. You have expressed concern over the impact of the proposed cuts to NASA's space and Earth science budget plans. If you were the NASA Administrator, what approach would you take to prioritize NASA's planned activities given the current constrained budgetary outlook for NASA, and why?

A2. I would stop missions that overrun significantly, and require a major replan—not simply a stretch out. These stretch outs put a major lien on the future; they are being used far too often. I would increase the emphasis on smaller missions, though I recognize that certain measurements require major efforts. These major efforts have proven to be very problematic. They require a far better technological base, and this requires sustained funding.

Q3. The impact of the cuts made to the space and Earth science budget plans relative to the FY05 runout has been exacerbated by cost growth in a number of science projects in recent years. What are the reasons for the cost growth, and what should be done to address it?

A3. There was adequate leadership in the past, and an inadequate technological base for the few missions that were planned and a very inadequate technological base for anything new. This leads to problems. Moreover, moving programs to the right only raises costs and rarely solves problems. In some cases, this shift to the right were caused by an inadequate funding wedge, and then the action of stretching out the program led to cost growth. The LandSat Data Continuity Missions needs to be carefully considered with an eye to cutting costs and requirements. With

the Global Precipitation Mission, there may have been "requires creep" (the mission continues to slip to the right); if so then this needs to be addressed. Finally and most importantly, the Earth science budget needs to be on a sounder footing—I would suggest a one percent ramp off the 2005 budget.

Q4. You paint a pretty bleak picture of the future of Earth Science in this country if current trends continue. What are the three most important things we need to do to ensure that Earth Observations programs remain viable?

A4. As stated, the Earth science budget needs to be on a sounder footing—I would suggest a one percent ramp off the 2005 budget. Second, there needs to be a technology program that establishes well the base for the missions that will be defined in the Decadal Survey—this requires focused and adequate funding, and not a shotgun approach with inadequate monies. Finally, the R&A program must have sufficient funding—the proposed FY07 budget does not provide sufficient funding.

Q5. In your testimony, you mention that the joint U.S.-Japan Global Precipitation Mission (GPM) will be delayed two and a half years as a result of this budget.

Q5a. What will be the impact of that delay—why does it matter when GPM flies?

A5a. The first order impact of the delay is that it raises costs and puts a lien in the timeframe of new opportunities. The data is also important, but the major impact is budgetary. The delay makes a bad situation worse.

Q5b. How high a priority should it be to restore GPM to an earlier launch date, and what would it take to make that happen?

A5b. I do not know, but the history is troubling—it continues to slip to the right and the costs then grow. This program needs to be examined and a detailed assessment done.

Q6. Under the proposed budget, will NASA be investing enough in technology risk reduction and concept development for NASA and the science community to be able to adequately assess the feasibility and likely cost of future missions such as the Terrestrial Planet Finder and the Einstein probes? Should we be concerned about NASA's level of investment in new technologies?

A6. NO to the first question and YES to the second.

Question submitted by Representative Mark Udall

Q1. Dr. Cleave indicates in her testimony that NASA will be evaluating the potential for lunar science enabled by the Exploration initiative.

- *How do we go about ranking such exploration-enabled lunar science against alternative science projects and ensuring we are getting the best science for our money?*

A1. Unfortunately, this is outside my range of expertise.

Question submitted by Representative Eddie Bernice Johnson

Q1. What impact will the empty promise of greater funding have on NASA's Science Mission Directorate's ability to plan long-term research initiatives?

A1. It would make a bad situation worse.

Questions submitted by Representative Michael M. Honda

Q1. Does it make sense to cancel the Deep Space Climate Observatory, which is a cost-effective project that has received strong support in the past, was rated as a high priority by the National Academies and plays an important role in infrastructure safety and science? How will canceling this mission impact our understanding of the Sun-Earth system and our efforts in Earth Science?

A1. I am not expert on this mission. It is my understanding that it would provide fresh and unique insight into the Earth radiation budget and hence climate change. Also, it provides an exciting new platform for understanding the Sun-Earth connection. Given the very troubling instrument cancellations in the NPOESS program, and particularly the Space Environment Sensor Suite, observations of space weather will be in short supply in the future.