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U.S. VISION FOR SPACE EXPLORATION

HEARING

BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED EIGHTH CONGRESS

SECOND SESSION

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U.S. VISION FOR SPACE EXPLORATION

THURSDAY, FEBRUARY 12, 2004

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

The Committee met, pursuant to call, at 10:08 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert (Chairman of the Committee) presiding.

HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

U.S. Vision for Space Exploration

THURSDAY, FEBRUARY 12, 2004
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Thursday, February 12th at 10:00 a.m., the Science Committee will hold a Full Committee hearing on the President's proposed space exploration initiative, which was announced Jan. 14. (A copy of the White House document that outlines the President's vision is attached as Attachment A.)

2. The President's Proposal

The President's plan can be seen as having three distinct, but related aspects. The first aspect concerns current human space flight programs. The President proposes to complete construction of the International Space Station (ISS) by the end of the decade and to retire the Space Shuttle at that point. ISS research is to be reconfigured to focus on questions related to the impact on human health of spending long periods in space. Under the proposal, the U.S. participation in ISS is slated to end around 2016, although the Administration has said that that date may shift. The National Aeronautics and Space Administration (NASA) has also decided to cancel the Shuttle mission that was needed to keep the Hubble Space Telescope in operation past 2007. Ending the Shuttle and Station programs is necessary to free up funds for other aspects of the proposal and to avoid Shuttle recertification in 2010, an expensive process called for by the *Columbia* Accident Investigation Board.

The second aspect of the plan concerns new medium-term goals for human space flight. The central goal is to return to the Moon between 2015 and 2020. To do this, NASA will develop a new Crew Exploration Vehicle (CEV), which will carry humans by 2014. (The CEV may also be used to service the Space Station.)

The third aspect of the plan concerns long-range goals for the years past 2020. The entire plan is geared toward preparing for this period, but what will happen during these years is (perhaps necessarily) left entirely open-ended. The ultimate goals are to send humans to Mars and to increase the commercial exploitation of space. The timing of future exploration is left open and will depend on the pace of technology development and discovery during the years leading up to 2020. The President announced the appointment of a nine-member commission, headed by former Secretary of the Air Force Pete Aldridge, that will focus primarily on recommending what kinds of things ought to be done in the long-run on the Moon and to get to Mars, and how those activities might shape programs in the nearer-term.

3. Overarching Questions

The President's plan raises many fundamental questions about the purposes of the U.S. space program and about the details of how it will be carried out. The overarching questions for the hearing include:

1. What is the *purpose* of the exploration program? To what degree will it be designed to answer scientific research questions? To what degree will it be designed to promote commercialization or national security interests? How high a national priority is exploration for exploration's sake?
2. How much will the President's proposal cost to implement now and in the future? What are the greatest uncertainties in the budget estimates that have been presented? When will those figures become more definite? Are there early points at which progress can reasonably be assessed? What is being done to avoid the inaccurate cost estimates that have plagued the Space Shuttle, Space Station and Orbital Space Plane programs?
3. What *budgetary tradeoffs* will have to be made to fund the President's proposal? Specifically, what will the impact be on NASA's programs in astronomy, outer planetary exploration, Earth science, and aeronautics?

The overall goal of the hearing is to make sure the Committee has clear information on the philosophy and budgetary assumptions that undergird the President's proposal.

4. Witnesses

Mr. Sean O'Keefe, Administrator of the National Aeronautics and Space Administration.

Dr. John Marburger, Director of the Office of Science and Technology Policy.

5. Issues

- **What is the goal of the President's initiative?** Human space travel is inherently expensive and risky compared to robotic missions. Congress needs to decide whether human space travel is a priority that merits continued funding, and obviously that will depend, in part, on what is to be gained. In his Jan. 14 speech, the President said, "We choose to explore space because doing so improves our lives and lifts our national spirit." But the Administration has sent mixed signals about what kinds of improvements will be sought. In some presentations, the Administration has left the impression that exploration is a basic human need, an end in itself—an activity that will be informed by science and may contribute to science, but that will not have a science-driven agenda. In other presentations, the Administration has implied that science is the primary rationale for the President's vision. In other places, commercialization, national security, and the possibility of technological spinoffs have been offered as rationales. None of these reasons is mutually exclusive, but the goals of the program will determine the spending and activities that are undertaken.
- **How much will the President's initiative cost?** The President has been clear that he is not willing to seek massive amounts of new spending to fund the initiative—unlike the approach that was taken during the Apollo program in the 1960s. NASA officials have said that if work does not proceed smoothly, they will extend deadlines rather than increase annual costs. (Moving deadlines would still increase cumulative costs.) The President has proposed a 5.6 percent increase for NASA (to $15.4 billion) for Fiscal Year (FY) 05, by far the largest increase for any R&D agency.

  Figuring out how much the President's initiative would cost is not easy because of the many assumptions that need to be made. Adding to the complexity, NASA has described the costs differently in different documents, using different baselines.

  The most specific figures concern the next five years (FY05–09), over which the President proposes to spend a cumulative total of $87.1 billion on the entire NASA budget. NASA has compared the proposal to two different baselines. In the first comparison, NASA says that over the next five years, the President proposes to spend $1 billion more on the entire NASA budget than NASA had predicted it would spend in February, 2003. (That estimate was made as part of the Presidents's FY04 budget.) In the second comparison, NASA describes the President's proposal as providing $12.6 billion more, cumulatively, over five years for the entire NASA budget compared to what NASA would have received if its spending had been frozen for five years at the FY04 level of about $15 billion. (NASA uses this figure frequently, but there is no evidence that NASA was ever going to face such a freeze.)

  Figuring out how much of the NASA budget will be dedicated to the President's initiative depends on what is included in that spending category. Should it include the Space Shuttle and Space Station? Should it include robotic missions that were planned before the President's announcement, but may contribute to it, or just new ones? NASA, generally, includes all robotic missions that will contribute to the initiative and excludes the Space Shuttle and Space Station. Using those definitions, the initiative would receive $31.4 billion over the next five years. Costs would increase considerably in the subsequent 10 years, and costs cannot even be estimated for the period beyond that because the activities remain undefined. (See Attachment B, although, according to NASA, the chart was designed more for internal purposes than to give a precise picture of out-year spending.)
- **What are the greatest uncertainties in NASA's cost projections?** Of necessity, the proposed budget is based on best guesses of costs for key elements of the President's initiative.

Perhaps the greatest uncertainty remains the cost of continuing to operate the Space Shuttle. Any delay in retiring the Space Shuttle will add significantly to NASA's costs (as well as raising the question of whether the Shuttle should fly without recertification). NASA continues to assume a return to flight this fall, although experts inside and outside the agency are raising doubts about whether that deadline can be met. Once flights resume, NASA plans about five flights a year—a pace that Admiral Gehman, the Chair of the *Columbia* Accident Investigation Board, has said could revive concerns about "schedule pressure" adversely affecting safety. Retiring the Shuttle on schedule may also require using means other than the Shuttle to take up crew and supplies to the Space Station because the Shuttle will be needed to complete Station construction. Shuttle retirement could also be delayed if key portions of the Station, such as the centrifuge being built by the Japanese, are not completed on schedule. (The centrifuge is generally viewed as the most valuable piece of scientific equipment that will be brought to the Station.) NASA is still figuring out the "manifests" for the remaining Shuttle flights—that is, the description of when flights would leave and return and what they would carry.

The costs of developing the CEV, the new vehicle that would take astronauts to the Moon and beyond also are uncertain because development has not yet begun. In some ways, CEV development will build on the Orbital Space Plane (OSP) project that NASA discontinued as part of the President's initiative. The OSP, which was to be designed primarily to take astronauts to the Space Station, was already facing cost overruns in its early design stages, and Congress was raising doubts about its usefulness. NASA now estimates that it will spend $6.5 billion over the next five years on CEV development.

The CEV will also require the development of a new launch system, and NASA has not decided yet how to approach the design of a new launch vehicle. NASA is now estimating that the development of such a vehicle will cost about $5 billion.

Administration officials have said that because the CEV and its launch system will be developed over a longer time period than was allotted for the OSP there will be time to reevaluate costs before becoming overly committed to a particular design. Total CEV development is expected to cost about $15 billion.

The cost of the CEV may be affected by how NASA decides to select a contractor for the program. NASA limited OSP development to two competitors. NASA has not yet made clear whether it will have a more open competition for the CEV.

- **How will the President's initiative affect the rest of NASA's programs?** The Space Sciences budget will continue to grow (from $3.9 billion in FY04 to $5.6 billion in FY09) because many of its robotics missions will be considered part of preparation for human exploration. Most of these missions will be entirely unchanged despite the redesignation. In addition, new lunar missions will be added. Nonetheless, projects totaling about $2.6 billion will be cut from the Space Sciences budget over the next five years (compared to the Administration's February, 2003 projections) by canceling or deferring missions and programs that are considered less important to human exploration. (Other projects are added so that, overall, Space Sciences will receive slightly more over the five-year period than had been planned, if one excludes Project Prometheus, which is being transferred from Space Sciences to another account.) One question is how Space Sciences will fare in the years after FY09 when the costs of a human lunar landing will begin to increase substantially.

  Earth Science would fare far worse, sustaining cuts in FY05 through FY08. Earth Science spending would decline from $1.52 billion in FY04 to $1.47 billion in FY09, a year in which it is slated to receive an increase. NASA Earth Science missions are a major component of the Administration's climate change science program.

  Aeronautics would be essentially flat through the period, increasing in some years and decreasing in others, but ending up in FY09 at $942 million—a drop from the FY04 level of $946 million.

  (See Attachment C for more details.)

- **Why is the Shuttle mission to the Hubble Space Telescope being cancelled?** The Administration is describing the Hubble cancellation as a "close call" made by the Administrator because of safety concerns. The Hubble, which has been enormously successful, is expected to go dark around 2007 without a servicing mission. Many astronomers are lobbying for that mission to occur, and, indeed, before the President's initiative was announced, a panel assembled by the National Academy of Sciences, called for another servicing mission to be added to extend the telescope's life even further. That request became moot with the decision to discontinue the Shuttle in 2010. However, some experts contend that ground-based telescopes have advanced so much in recent years that they can now make up for at least some of the capability that would be lost if the Hubble ceases to function.

  A Shuttle mission to the Hubble is a special case because Hubble missions cannot reach the Space Station, which could be used as a "safe haven" in case of an emergency or the need to inspect or repair the Shuttle. The Columbia Accident Investigation Board said that the Shuttle should fly to destinations other than the Space Station only when NASA had developed an "autonomous" inspection and repair capability—that is, a way to inspect without using the Space Station. NASA believes such a capability is probably many years away. As a substitute, NASA examined having a second Shuttle ready to fly a rescue mission, but viewed that as dangerous and prohibitively expensive. However, debate continues among Hubble enthusiasts as to the relative dangers of a mission to the Station and a mission to Hubble.

  NASA acknowledges that there were "secondary" considerations that also led to the cancellation of the Hubble mission, including the need to complete all the Shuttle missions needed for Station construction by 2010.

- **How will the President's initiative change the Space Station program?** As a result of the initiative, NASA is re-examining the entire Station research program. Decisions on the new program may not be made for about a year. The new program will focus on questions of human health. Among the questions this raises are: what research will be discontinued and was any of it of real value? How much will the new research agenda cost? Does the new research really require facilities in space and will it be peer reviewed? Will concerns arise since much of the new research will presumably involve using astronauts as human experimental subjects?

- **How will NASA transport crews to the Station after the Shuttle is retired?** The Administration acknowledges that it has not yet figured out how to get crews to the Station between the retirement of the Shuttle in 2010 and the first flight of the CEV in 2014. (The Shuttle may also be unavailable for crew transfer earlier, if its schedule needs to be devoted entirely to Station construction.)

  The U.S. is already using the Russian Soyuz spacecraft for crew transfer while the Shuttle is grounded. However, it is doing so under an agreement that the Russians will have fulfilled by 2006. Renewing the agreement may require a change in the Iran Nonproliferation Act (INA), which Congress passed in 2000. That Act attempts to prevent the spread of weapons of mass destruction to Iran by prohibiting the purchase of Russian rockets by the U.S. unless the President certifies that no Russian entity is engaged in any sales of missiles or missile systems to Iran. (The INA does not apply to the current agreement.)

  Amending the Act would be controversial, and so far the Administration has hedged its bets, simply saying that the matter is under review.

- **How will NASA carry cargo to and from the Station after the Shuttle is retired?** Similar to the crew situation, NASA has no current plan for getting cargo to the Station after the Shuttle is retired. NASA is using Russian Progress vehicles while the Shuttle is grounded, but continuing to do so indefinitely could require amending the Iran Nonproliferation Act. (See above.) NASA might also rely on Europe or Japan, which are partners in the Space Station and which are developing cargo-carrying spacecraft of their own. But those craft have not yet been flight-tested. Some have suggested that NASA could convert the space shuttle itself into a cargo-only craft that could deliver huge loads of cargo to the ISS. But critics have said that such an approach would be much more expensive than flying smaller loads on existing rockets. Finally, NASA might try to purchase the services of commercial rocket firms. But at present no firm has a rocket that can supply the Station, although sev-

eral have indicated a willingness to try to carry small amounts of cargo there. Another complication is that some cargo for the Space Station is very large—major replacement parts, for example—and most craft other than the Shuttle are not big enough to carry such cargo.

6. Questions to witnesses:

In his letter of invitation to appear as a witness, Administrator O'Keefe was asked to address the following questions in his testimony:

(1) What specific activities must be undertaken and milestones achieved over the next twelve months and over the next five years to implement the new initiative? What analysis was performed to ensure that the proposed budget is adequate to accomplish those activities?

(2) Specifically, what changes (in spending and program content) are contemplated in the Shuttle, International Space Station, and Space Science programs as a result of the new initiative?

(3) What is the current status of NASA's thinking about a mission to the Hubble Space Telescope? What changes in spending and in other NASA activities would be necessary to allow one or two more missions to the Hubble?

(4) Are any changes to the Iran Non-proliferation Act, the Space Station Inter-Governmental Agreement or any other agreements required to complete the Space Station? If so, please explain how the Administration plans to inform and consult with the Congress on these changes, including the timetable for any actions that may be necessary.

In his letter of invitation to appear as a witness, Dr. Marburger was given the following information and asked to address the following questions in his testimony:

In their briefings on the initiative, White House officials have said that you were an active participant in developing the initiative, and that, more specifically, you had reviewed the initiative to ensure that no essential science activities would be sacrificed to pay for it.

In your testimony, you should describe the role you and your staff played in formulating the initiative and why and how you concluded that the initiative would be a net benefit from a scientific point of view. As part of that description, please specifically address the following:

(1) What criteria did you use to determine whether an activity was "essential," and how did you evaluate and balance the differing scientific benefits of existing and potential NASA activities?

(2) To what extent, has and can the International Space Station contribute to science? Did you review any specific new research agenda for the Space Station as part of your evaluation of the overall initiative?

(3) To what extent can scientific research that would be accomplished by manned missions to the Moon be accomplished by space telescopes or by unmanned probes on the Moon?

(4) How would you describe the contributions to science made by the Hubble Space Telescope? How would you assess what would be lost if the Hubble ceases to function earlier than had been planned? How did you weigh those losses against the potential benefits of other activities under the new initiative?"

7. Attachments

Attachment A: *A Renewed Spirit of Discovery: The President's Vision for U.S. Space Exploration*

Attachment B: NASA Budget Projection 2004–2020. (This chart can be viewed in color on the Internet at *http://www.nasa.gov/pdf/54873main_budget_chart_14jan04.pdf*

Attachment C: NASA FY 2005 Budget

Attachment A

A Renewed Spirit of Discovery

The President's Vision for U.S. Space Exploration

PRESIDENT GEORGE W. BUSH

JANUARY 2004

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b. Mars and Other Destinations

C. Space Transportation Capabilities Supporting Exploration

D. International and Commercial Participation

Background

From the Apollo landings on the Moon, to robotic surveys of the Sun and the planets, to the compelling images captured by advanced space telescopes, U.S. achievements in space have revolutionized humanity's view of the universe and have inspired Americans and people around the world. These achievements also have led to the development of technologies that have widespread applications to address problems on Earth. As the world enters the second century of powered flight, it is time to articulate a new vision that will define and guide U.S. space exploration activities for the next several decades.

Today, humanity has the potential to seek answers to the most fundamental questions posed about the existence of life beyond Earth. Telescopes have found planets around other stars. Robotic probes have identified potential resources on the Moon, and evidence of water -- a key ingredient for life -- has been found on Mars and the moons of Jupiter.

Direct human experience in space has fundamentally altered our perspective of humanity and our place in the universe. Humans have the ability to respond to the unexpected developments inherent in space travel and possess unique skills that enhance discoveries. Just as Mercury, Gemini, and Apollo challenged a generation of Americans, a renewed U.S. space exploration program with a significant human component can inspire us -- and our youth -- to greater achievements on Earth and in space.

The loss of Space Shuttles *Challenger* and *Columbia* and their crews are a stark reminder of the inherent risks of space flight and the severity of the challenges posed by space exploration. In preparation for future human exploration, we must advance our ability to live and work safely in space and, at the same time, develop the technologies to extend humanity's reach to the Moon, Mars, and beyond. The new technologies required for further space exploration also will improve the Nation's other space activities and may provide applications that could be used to address problems on Earth.

Like the explorers of the past and the pioneers of flight in the last century, we cannot today identify all that we will gain from space exploration; we are confident, nonetheless, that the eventual return will be great. Like their efforts, the success of future U.S. space exploration will unfold over generations.

Goal and Objectives

The fundamental goal of this vision is to advance U.S. scientific, security, and economic interests through a robust space exploration program. In support of this goal, the United States will:

- Implement a sustained and affordable human and robotic program to explore the solar system and beyond;

- Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;

- Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and

- Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

Bringing the Vision to Reality

The Administrator of the National Aeronautics and Space Administration will be responsible for the plans, programs, and activities required to implement this vision, in coordination with other agencies, as deemed appropriate. The Administrator will plan and implement an integrated, long-term robotic and human exploration program structured with measurable milestones and executed on the basis of available resources, accumulated experience, and technology readiness.

To implement this vision, the Administrator will conduct the following activities and take other actions as required:

A. Exploration Activities in Low Earth Orbit

Space Shuttle

- Return the Space Shuttle to flight as soon as practical, based on the recommendations of the Columbia Accident Investigation Board;
- Focus use of the Space Shuttle to complete assembly of the International Space Station; and
- Retire the Space Shuttle as soon as assembly of the International Space Station is completed, planned for the end of this decade;

International Space Station

- Complete assembly of the International Space Station, including the U.S. components that support U.S. space exploration goals and those provided by foreign partners, planned for the end of this decade;

- Focus U.S. research and use of the International Space Station on supporting space exploration goals, with emphasis on understanding how the space environment affects astronaut health and capabilities and developing countermeasures; and

- Conduct International Space Station activities in a manner consistent with U.S. obligations contained in the agreements between the United States and other partners in the International Space Station.

B. Space Exploration Beyond Low Earth Orbit

The Moon

- Undertake lunar exploration activities to enable sustained human and robotic exploration of Mars and more distant destinations in the solar system;

- Starting no later than 2008, initiate a series of robotic missions to the Moon to prepare for and support future human exploration activities;

- Conduct the first extended human expedition to the lunar surface as early as 2015, but no later than the year 2020; and

- Use lunar exploration activities to further science, and to develop and test new approaches, technologies, and systems, including use of lunar and other space resources, to support sustained human space exploration to Mars and other destinations.

Mars and Other Destinations

- Conduct robotic exploration of Mars to search for evidence of life, to understand the history of the solar system, and to prepare for future human exploration;

- Conduct robotic exploration across the solar system for scientific purposes and to support human exploration. In particular, explore Jupiter's moons, asteroids and other bodies to search for evidence of life, to understand the history of the solar system, and to search for resources;

- Conduct advanced telescope searches for Earth-like planets and habitable environments around other stars;

- Develop and demonstrate power generation, propulsion, life support, and other key capabilities required to support more distant, more capable, and/or longer duration human and robotic exploration of Mars and other destinations; and

- Conduct human expeditions to Mars after acquiring adequate knowledge about the planet using robotic missions and after successfully demonstrating sustained human exploration missions to the Moon.

C. Space Transportation Capabilities Supporting Exploration

- Develop a new crew exploration vehicle to provide crew transportation for missions beyond low Earth orbit;

- Conduct the initial test flight before the end of this decade in order to provide an operational capability to support human exploration missions no later than 2014;

- Separate to the maximum practical extent crew from cargo transportation to the International Space Station and for launching exploration missions beyond low Earth orbit;

  - Acquire cargo transportation as soon as practical and affordable to support missions to and from the International Space Station; and

  - Acquire crew transportation to and from the International Space Station, as required, after the Space Shuttle is retired from service.

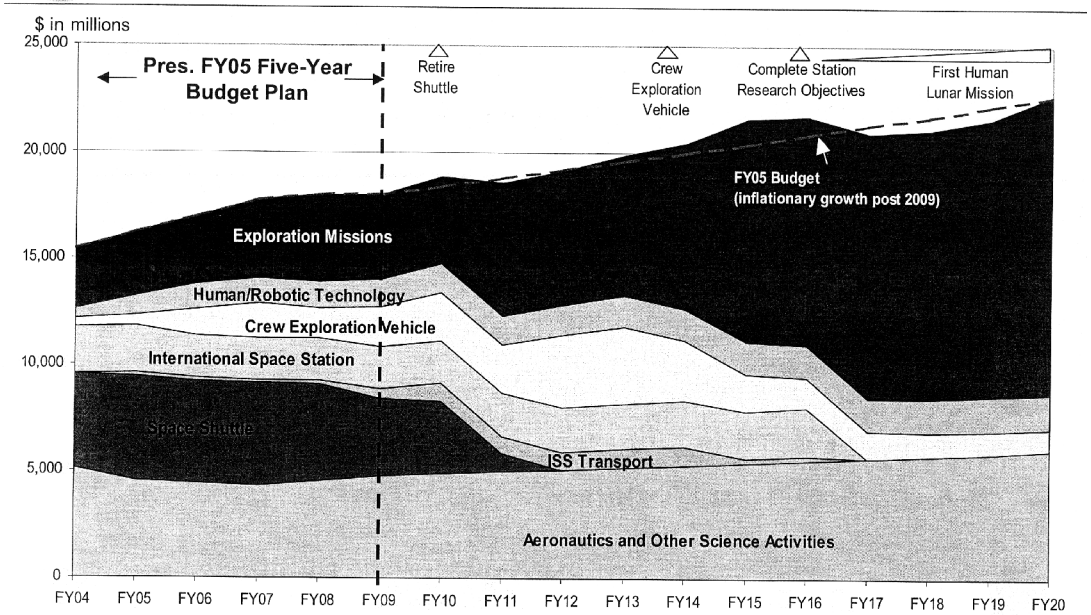
D. International and Commercial Participation

- Pursue opportunities for international participation to support U.S. space exploration goals; and

- Pursue commercial opportunities for providing transportation and other services supporting the International Space Station and exploration missions beyond low Earth orbit.

Attachment B

Strategy Based on Long-Term Affordability



NOTE: Exploration missions – Robotic and eventual human missions to Moon, Mars, and beyond
Human/Robotic Technology – Technologies to enable development of exploration space systems
Crew Exploration Vehicle – Transportation vehicle for human explorers
ISS Transport – US and foreign launch systems to support Space Station needs especially after Shuttle retirement

Added Budget for Exploration Vision

($ in billions)	2005	2006	2007	2008	2009	TOTAL
Lunar Exploration	0.1	0.1	0.3	0.4	0.4	
Mars Exploration	0.7	0.7	0.9	1.2	1.3	
Other Solar System Explor.	1.2	1.2	1.3	1.4	1.4	
Origins	1.1	1.2	1.2	1.2	0.9	
Human/Robotic Technology	1.1	1.3	1.3	1.4	1.4	
Project Constellation	0.4	1.3	1.6	1.4	1.9	
Exploration Specific	**4.5**	**5.8**	**6.7**	**6.9**	**7.4**	**31.4**
Space Shuttle	4.3	4.3	4.3	4.0	3.0	
Space Station	1.7	1.6	1.6	1.6	1.6	
ISS Transport	0.1	0.2	0.2	0.2	0.5	
Other	1.0	0.8	0.8	0.8	0.8	
ISS/Shuttle & Related	**7.2**	**6.9**	**6.9**	**6.6**	**5.9**	**33.5**
Earth Science	1.5	1.4	1.4	1.3	1.5	
Aeronautics	0.9	1.0	0.9	0.9	0.9	
Other	2.1	1.9	2.0	2.2	2.3	
Rest of budget	**4.5**	**4.3**	**4.3**	**4.5**	**4.7**	**22.3**
Agency Total	**16.2**	**17.0**	**17.8**	**18.0**	**18.0**	**87.1**
Amount above $15B freeze	1.3	2.1	2.9	3.1	3.1	12.6

$12B Add

Attachment C

NASA's FY2005 Budget
($ in millions)

By Appropriations Account / By Enterprise / By Theme	FY 2004 Enacted	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	Delta FY04-05 $	Delta FY04-05 %	Delta FY05-09 $	Delta FY05-09 %	Total FY05-09
Exploration, Science & Aeronautics	7,831	7,760	7,869	8,320	8,900	9,091	-71	-0.9%	1,331	17.2%	41,941
Space Science	3,944	4,138	4,404	4,906	5,520	5,561	195	4.9%	1,423	34.4%	24,528
Solar Systems Exploration	1,302	1,187	1,202	1,300	1,392	1,438	-115	-8.8%	252	21.2%	6,519
Mars Exploration	595	691	724	944	1,188	1,268	96	16.1%	578	83.6%	4,815
Lunar Exploration		70	135	280	375	420	70	n/a	350	500.0%	1,280
Astronomical Search for Origins	894	1,067	1,196	1,212	1,182	927	173	19.4%	-140	-13.1%	5,584
Structure & Evolution of the Universe	404	378	365	382	425	457	-26	-6.4%	79	20.9%	2,007
Sun-Earth Connections	749	746	781	788	958	1,051	-3	-0.4%	305	40.9%	4,324
Earth Science	1,525	1,485	1,390	1,368	1,343	1,474	-40	-2.6%	-11	-0.7%	7,060
Earth System Science	1,451	1,409	1,313	1,290	1,266	1,397	-43	-2.9%	-12	-0.8%	6,675
Earth Science Applications	74	77	77	77	77	77	3	3.4%	1	0.7%	385
Biological & Physical Research	965	1,049	950	938	941	944	84	8.7%	-105	-10.0%	4,822
Biological Sciences Research	356	492	499	496	500	502	136	38.2%	10	2.0%	2,489
Physical Sciences Research	350	300	220	210	210	210	-50	-14.3%	-90	-30.0%	1,150
Research Partnerships & Flight Supt	259	257	232	232	231	232	-2	-0.8%	-25	-9.7%	1,184
Aeronautics	946	919	957	938	926	942	-27	-2.9%	23	2.5%	4,682
Aeronautics Technology	946	919	957	938	926	942	-27	-2.9%	23	2.5%	4,682
Education	164	169	169	171	170	170	5	3.0%	1	0.6%	849
Education	164	169	169	171	170	170	5	3.0%	1	0.6%	849
Earmarks**	287										
Exploration Capabilities	7,521	8,456	9,104	9,465	9,070	8,911	936	12.4%	455	5.4%	45,006
Exploration Systems*	1,563	1,782	2,579	2,941	2,809	3,313	219	14.0%	1,531	85.9%	13,424
Human & Robotic Technology	655	1,094	1,318	1,317	1,386	1,450	439	67.1%	356	32.6%	6,565
Transportation Systems	909	689	1,261	1,624	1,423	1,863	-220	-24.2%	1,174	170.5%	6,860
Space Flight	5,857	6,674	6,525	6,524	6,261	5,598	817	14.0%	-1,076	-16.1%	31,582
Space Station	1,497	1,863	1,764	1,780	1,779	2,115	366	24.5%	252	13.5%	9,301
Space Shuttle	3,928	4,319	4,326	4,314	4,027	3,030	391	10.0%	-1,289	-29.8%	20,016
Space Flight Support	432	492	435	430	456	453	60	13.9%	-39	-7.9%	2,266
Earmarks**	101										
Inspector General	27	28	29	30	31	32	1	3.7%	4	14.3%	150
TOTAL	15,378	16,244	17,002	17,815	18,001	18,034	866	5.6%	1,790	11.0%	87,097
year to year increase		5.6%	4.7%	4.8%	1.0%	0.2%					

*In FY2004 Exploration Systems replaces Crosscutting Technologies
**FY2004 budget column does not allocate earmarks across Enterprises
NOTE: May not add due to rounding

Chairman BOEHLERT. Good morning. I want to welcome everyone here for the first of what I am sure will be many hearings on the President's Space Exploration Initiative. Our goal today is to get as many facts on the table as possible. Congress can only have a sensible and definitive debate on space policy if we are all working with the same understandings and assumptions. But policy questions before us are tough enough without a fight over the facts in the case. And I think everyone concerned with this issue should expect lengthy and spirited debate before Congress decides how to proceed, which could easily take us to the end of this calendar year.

So what do we hope to better understand at the end of today's session? We want a clear description of the goals of the proposed initiative, the ways it is expected to contribute to science, security, and the economy. We need a clear understanding of the cost of the initiative, what has been assumed in developing cost estimates, and how those estimates are most likely to change. We need to get more operational details of the initiative, for example, how the Space Station will be serviced after 2010. And we need a fuller explanation of the impact of the policy. How will it affect Earth science and aeronautics and other NASA programs?

Right now, we have far more questions than answers, and I look forward to hearing from our witnesses today, who are among the key architects of this new policy. We are going to need very direct and precise guidance from them.

As you might have already gathered, I remain open-minded about this proposal. The President and his top advisors are to be congratulated for having done what no one has been able—willing to do for more than 40 years: lay out a well thought out space policy with a seemingly reasonable price tag. The President has made hard choices. I know I agree with some of those choices. For example, I have been calling for the past year for a date certain to end the Shuttle and Space Station programs. The President's proposal provides those dates, although we still have to examine whether the right endpoints were selected.

But I still need much more information about the goals and costs before I can decide whether I decide the particular choices the President has made in this proposal. I have to say that this is hardly the ideal year for this proposal to have come forward, although, perhaps, there never would be an ideal year. But the increase proposed for NASA is especially conspicuous in a budget in which basic research increases by only ½ a percentage point. Indeed, non-Defense, non-Homeland discretionary spending, as a whole, increases only by that same slim amount.

Is this initiative a high enough priority, a pressing enough priority, to be funded in such a budget? I don't know. And we have to remember that the percentage increases required in the years before fiscal year 2009, if not before, may also turn out to be significant.

So I am in a quandary, quite frankly. And the answers we get today will help me determine which way to turn. I imagine that will be true of others on the panel and certainly of others in the Congress. The advance of human space flight is an engaging dream, but I want to know how we are going to feel when we wake up. Will we have advanced human knowledge? Will we have en-

abled our nation to be more respected, more secure, and more prosperous? Will we have behaved responsibly in meeting the needs of the American people? Will we, in short, have helped this nation remain what Abraham Lincoln, born this day, called "The last best hope of Earth"? These are, perhaps, the toughest questions we will confront at a hearing this year.

I look forward to hearing our witnesses provide the specifics that will help me figure out the answers.

Mr. Gordon.

[The prepared statement of Chairman Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD BOEHLERT

I want to welcome everyone here for the first of what I'm sure will be many hearings on the President's Space Exploration Initiative.

Our goal today is to get as many facts on the table as possible. Congress can only have a sensible and definitive debate on space policy if we're all working with the same understandings and assumptions. The policy questions before us are tough enough without a fight over the facts of the case. And I think everyone concerned with this issue should expect a lengthy and spirited debate before Congress decides how to proceed—which could easily take to the end of this calendar year.

So what do we hope to better understand at the end of today's session? We want a clearer description of the goals of the proposed initiative—the ways it's expected to contribute to science, security and the economy. We need a clearer understanding of the costs of the initiative—what's been assumed in developing cost estimates and how those estimates are most likely to change. We need to get more operational details of the initiative—for example, how the space station will be serviced after 2010. And we need a fuller explanation of the impact of the policy—how it will affect Earth science and aeronautics and other NASA programs.

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The President has made hard choices. I know I agree with some of those choices. For example, I have been calling for the past year for a date certain to end the Shuttle and Space Station programs. The President's proposal provides those dates, although we still have to examine whether the right endpoints were selected.

But I still need much more information about goals and costs before I can decide whether I support the particular choices the President has made in this proposal. I have to say that this is hardly the ideal year for this proposal to have come forward—although perhaps there never would be an ideal year. But the increase proposed for NASA is especially conspicuous in a budget in which basic research increases by only half a percentage point. Indeed, non-defense, non-homeland discretionary spending as a whole increases only by that same slim amount.

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Will we have advanced human knowledge? Will we have enabled our nation to be more respected, more secure, and more prosperous? Will we have behaved responsibly in meeting the needs of the American people? Will we, in short, have helped this nation remain what Abraham Lincoln—born this day—called "the last, best hope of Earth"? These are perhaps the toughest questions we'll confront at a hearing this year.

I look forward to having our witnesses provide the specifics that will help me figure out my answers.

Mr. Gordon.

Mr. GORDON. Thank you, Mr. Chairman, and good morning.

I want to thank the Chairman for welcoming the witnesses—or to join the Chairman in welcoming the witnesses to today's hearing. And I want to thank Chairman Boehlert for convening this hearing on the President's new Space Exploration Initiative. It is clear that the proposal has the potential to result in significant changes to NASA's programs and future direction as an agency. We need to hear more about it.

First, however, I would like to state that I am pleased that the President has proposed some specific, long-term goals for the Nation's human space flight program. That is something that Members on both sides of the aisle have been urging for some time. I think it is appropriate for this nation to make a sustained commitment to human and robotic exploration of the Solar System, and I also welcome the President's speech to that matter. And I think that an incremental approach, starting with a sustained presence on the Moon makes a lot of sense for many reasons.

History has shown that past investments in our space program have resulted in new discoveries and technologies that have delivered significant benefits to our citizens. I have no doubt that we will learn much from future exploration missions, and the American people will garner benefits, both tangible and intangible, from our expansion into the Solar System.

Of course, after further review, Congress and the American people may conclude that NASA's plans for implementing the President's goals are unrealistic or unaffordable, or both. If so, that doesn't mean that the Nation should walk away from the long-term exploration goals. It just means that we have more work to do to craft a plan that is workable and sustainable.

As we examine NASA's plan, I will be looking for answers to a number of questions, including: one, what will the impact of the President's initiative on NASA—be on NASA and other important activities? I am particularly concerned that NASA's other missions not be cannibalized, whether over the short-term or the long-term to cover the cost of this initiative.

Second, how confident should we be that NASA and the White House have a good understanding of the cost of their proposal and have a budget plan that truly reflects those cost? NASA has had a mixed record on the credibility of its budgeting, and we need to be convinced that NASA is not being overly optimistic in its cost estimates. In that regard, I would simply note that the former President, George H. W. Bush, proposed a similar program in 1989. His OMB Director estimated its 30-year costs to be about $590 billion in 2003-dollar terms. If that is what NASA is now estimating, I hope that the budget plans reflect it. If NASA thinks it can be done cheaper, then we need to understand why.

Third, what are the implications of some of the policy decisions embedded in the President's initiative? In particular, what will it mean to terminate the Space Shuttle Program years before another American spacecraft is available to get U.S. astronauts into space? It is clear that we will be dependent on the kindness of others, in this case, the Russians, to have any way of getting our astronauts to and from the Space Station. What if the Soyuz fleet is grounded or unavailable to us for whatever reason? What is plan B?

Well, there is much to cover, and I hope that this hearing will mark the beginning of a thorough review of the initiative. I also hope that the President will choose to speak out on this space initiative. This will not be an easy year to start a major new initiative in the face of a growing deficit. The President is going to have to make the case that this initiative is a high priority if it is going to survive for more than one or two sessions in Congress.

With that, I, again, want to welcome our witnesses, and I look forward to your testimony.

[The prepared statement of Mr. Gordon follows:]

PREPARED STATEMENT OF REPRESENTATIVE BART GORDON

Good morning. I want to join the Chairman in welcoming the witnesses to today's hearing. And I want to thank Chairman Boehlert for convening this hearing on the President's new space exploration initiative. It is clear that the proposal has the potential to result in significant changes to NASA's programs and future direction as an agency. We need to hear more about it.

First, however, I would like to state that I am pleased that the President has proposed some specific long-term goals for the Nation's human space flight program. That is something that Members on both side of the aisle have been urging for some time. I think that it is appropriate for this nation to make a sustained commitment to the human and robotic exploration of the solar system, and so I welcome the President's speech. And I think that an incremental approach, starting with a sustained presence on the Moon, makes a lot of sense for many reasons.

History has shown that past investments in our space program have resulted in new discoveries and technologies that have delivered significant benefits to our citizens. I have no doubt that we will learn much from future exploration missions, and the American people will garner benefits both tangible and intangible from our expansion into the solar system.

Of course, after further review Congress and the American people may conclude that NASA's plans for implementing the President's goals are unrealistic or unaffordable or both. If so, that doesn't mean that the Nation should walk away from the long-term exploration goals. It just means that we have more work to do to craft a plan that *is* workable and sustainable.

As we examine NASA's plans, I will be looking for answers to a number of questions. First, what will be the impact of the President's initiative on NASA's other important activities? I am particularly concerned that NASA's other missions not be cannibalized—whether over the short-term or the long-term—to cover the cost of the initiative.

Second, how confident should we be that NASA and the White House have a good understanding of the cost of their proposals—and have a budget plan that truly reflects those costs? NASA has had a mixed record on the credibility of its budgeting, and we will need to be convinced that NASA is not being overoptimistic in its cost estimates. In that regard, I would simply note that when President George H.W. Bush proposed a similar program in 1989, his OMB director estimated its 30-year cost to be about $590 billion (in 2003 year dollars). If that is what NASA is now estimating, I hope that the budget plans reflect it. If NASA thinks it can be done cheaper, we will need to understand the reasons why.

Third, what are the implications of some of the policy decisions embedded in the President's initiative? In particular, what will it mean to terminate the Space Shuttle program *years* before another American spacecraft is available to get U.S. astronauts into space? It is clear that we will be dependent on the kindness of others—in this case the Russians—to have any way of getting our astronauts to and from the Space Station. What if the Soyuz fleet is grounded or unavailable to us—for whatever reason. What is the "Plan B"?

Well, there is much to cover, and I hope that this hearing will mark the beginning of a thorough review of the initiative. I also hope that the President will choose to speak out on his space initiative. This will not be an easy year to start major new initiatives in the face of the growing deficit, the need for continued spending for the Iraq war, and the increase in the Medicare cost estimate. The President is going to have to make the case that this initiative is a high priority if it is going to survive for more than one session of Congress.

With that, I again want to welcome our witnesses, and I look forward to your testimony.

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

The Chair recognizes the Chairman of the Subcommittee on Space and Aeronautics, Mr. Rohrabacher.

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

How many times have we pointed to this slogan on the wall? All right. And how many times have we said we want a vision statement, we want a—some guidance from the President, a long-term strategy? And we got it. And the President has indicated very strongly in that speech and his—and what has happened since then that he has got a game plan for us, and he has done his part of the job, at least he has started doing his part of the job. Now it is up to us to do our part of the job. It is the time for Congress to get on board.

And one thing that makes a strategy is that one—is that you are setting priorities. And where I respectfully disagree with my good friend, Mr. Gordon, I expect the President to cannibalize other programs in order to make this strategy work. That is called setting priorities. What we need to do, however, is to make sure that those decisions, and this I would agree with Mr. Gordon, are clear decisions made that this priority is more important than another and thus we are taking funds intentionally in order to make sure that the President succeeds in the goals that he has established.

And Mr. O'Keefe, you can count on me, and I know you can count on the other Members in this committee, to work with you if, indeed, the President is serious about the vision that he laid out. And I am banking on the fact that he is serious and that we are going to do a job here and that we are going to start our way back to the Moon and then beyond. With your leadership, and then perhaps when we are—10 years or 20 years from now, there will be a whole new set of characters, but we will have laid the foundation for the great success that they will accomplish.

Mr. Chairman, I commend your decision of holding this critical hearing today. As you know, I have been a strong advocate of returning to the Moon and establishing a permanent manned site there. Now the President has given NASA a vision that may help us realize that dream as a stepping stone, of course, to even more further explorations of the universe. Someday, lunar settlements may be, and will be, thriving and growing, increasing our natural resources, the natural resources that are available to us, and perhaps providing us abundant energy, but most certainly expanding our scientific knowledge in creating future industries that we can only now imagine. In fact, citizen astronauts not only will contribute to our economic development, but also to our national standing in leadership in science and engineering as well.

First and foremost, this outlook for the future must be built on a foundation of credible and affordable near and far-term technologies, and that is basically what we are going to be talking about: the development of these technologies, how to pay for it, when we expect them to come on board, what—how that relates to the plan. But experience has shown that the private sector's innovative approaches are just as important as what government is doing. So let us, as we move forward, not look at this as simply a government enterprise. What the President laid out was a National vision, not just a bureaucratic or governmental process.

Emerging space entrepreneurs have demonstrated that space activities are no longer limited to the government domain and that making a profit is critical to enabling the private sector to make investments in space. If we make it profitable, we have a vision—the vision of the Moon includes something where the private sector is going to make a profit in helping us accomplish this—that mission, we can expect private sector investment to help the taxpayers. The successful development of new space industries will undoubtedly hinge on expanding market opportunities. And the new space exploration mandate calls for promoting commercial space.

And however, let me just say that at this moment, I am uncertain exactly what NASA's plans are for the commercial part of this and how to attract private sector investment into the technologies and into the goals that we wish to achieve. We can't expect to have that right now, but I know that that is going to be an area of discussion for the next few months and, perhaps, the rest of this year. NASA must make clear how its long-term investment in the future exploration activities will support a combination of focused manned missions, robotic exploration, and private sector initiatives. Anything less threatens the credibility of the President's space vision.

And again, let me say, you have our 100 percent support, and I am looking forward to working with you, Mr. O'Keefe, in making this vision a reality.

Thank you.

[The prepared statement of Mr. Rohrabacher follows:]

PREPARED STATEMENT OF REPRESENTATIVE DANA ROHRABACHER

Mr. Chairman, I commend your decision in holding this critical hearing early in the session. As you know, I have been a staunch advocate for us returning to the Moon and establishing a permanent manned site. Now the President has given NASA the vision in helping us realize this deferred dream.

Someday lunar settlements will be thriving and growing, increasing our natural resources at our disposal, providing abundant energy, expanding our scientific knowledge, and creating future industries that we can only imagine. In fact, citizen astronauts not only will contribute to our economic development, but to our national standing and leadership in science and engineering as well.

First and foremost, this outlook of the future must be built upon a foundation of credible and affordable near- and far-term technologies. Experience has shown that the private sector's innovative approach in solving space-related problems has proved to be invaluable.

Emerging space entrepreneurs have demonstrated that space activities are no longer limited to the government domain, and that making profits are critical in enabling private sector investments in space. The successful development of new space industries will undoubtedly hinge on expanding market opportunities. The new space exploration mandate calls for promoting commercial space, but NASA is unclear how private space ventures will support missions to low-Earth orbit.

NASA must make clear how its long-term investments in future exploration activities support an intelligent combination of focused manned missions, robotic exploration, and private-sector initiatives. Anything less threatens the credibility of the President's space vision. Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you very much, Mr. Rohrabacher. And like you, as I indicated in my opening statement, I want to applaud the President's vision, but I would like to add that before we get on board and—we have to determine the extent of the ticket we are willing to purchase for the journey. And that is why it is so critically important that we get very precise in addressing the timetables, the dollars, and the impact on science overall. And that is why I welcome Dr. Marburger here, because this is critically im-

portant that we hear from the President's Science Advisor on how this critical component of an overall package fits in with everything else.

With that, I recognize the Subcommittee Chairman—a Ranking Member on Space and Aeronautics, Mr. Lampson.

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

I want to join my colleagues in welcoming Dr. Marburger and Administrator O'Keefe to this morning's hearing. It is, indeed, a very important one.

I hope it is just the first, as it has been said, in a series of hearings to examine the President's proposed initiative as well as to review the overall NASA budget request.

For me, the President's announcement of some long-term goals for the Nation's human space flight program was both welcome and overdue. I have long been pushing for a commitment to a sustained exploration agenda with a series of exciting and significant intermediate milestones on the way to Mars. I introduced legislation to that effect in the last Congress and I reintroduced it again in this Congress. I welcome the President's decision to put forth an exploration agenda, and I look forward to working with him to advance its goals.

I think space exploration brings out the best of us in us, as a people. With that said, I am going to also need to be convinced that the implementation plan laid out by NASA is, in fact, both credible and sustainable before I can give it my unreserved support. I found it interesting this—that this morning's *Washington Post* had an article on the meeting yesterday, the Commission—Space Exploration Commission meeting where Norman Augustine, the retired Chairman of Lockheed Martin, made comments that NASA doesn't have enough money or bright young stars to achieve President Bush's goal of returning astronauts to the Moon and flying from there to Mars, and "it would be a grave mistake to undertake a major new space objective on the cheap," he said. "To do so, in my opinion, would be an invitation to disaster." And in that same article, there was a quote from General Lester Lyles, who is retired from the Air Force, about the possibility that budgets and technologies of other government agencies could even be tapped. So it would be interesting to know, Mr. Marburger—or Dr. Marburger, if those were certainly plans or thoughts that you have.

We will do no favor to the dedicated men and women of NASA if we fail to ask the tough questions about the President's initiative. For example, what will be the impact of the President's plan on NASA's other programs? I agree with my colleague, Mr. Gordon. I am not prepared to do damage to NASA's other programs, its other important activities, in order to make this new plan fit within the budget—President's budget. Those who know me know that I am an unabashed supporter of NASA's human space flight program and of the good work done, particularly at the Johnson Space Center.

Human space flight is an important part of our nation's overall space effort, and it has delivered significant technological and other benefits to our citizens over the years, but it is only one of NASA's missions. I don't know how many of you saw the news about the local law enforcement officials getting help from NASA technology

in identifying the suspect in the tragic abduction and murder of Carli Bruscha in Florida just recently. And what you may not know is that the technology was first developed by two NASA employees: one a solar physicist, and the other atmospheric scientist, to assist them in their research activities. So it is a poignant but an important example of the ways in which our investments in all areas of the space program concern the broader needs of our society.

As you know, the House recently passed NASA workforce legislation to improve NASA's ability to attract and retain the best and the brightest. What message will we send if we now embrace an exploration plan that tells a range of dedicated NASA employees, "Thanks for your hard work, but we now need your budget for our new initiative"? It seems to me that the President needs to propose funding adequate to do the job right or NASA, regrettably, will have to scale back its aspirations.

My own strong preference is that the President provide the funding needed to do the job right. We, in Congress, will work to do it, but fundamentally, I don't want to put the NASA employees in the situation of once again trying to fit 10 pounds of new tasks into a five-pound budgetary pack.

Mr. Chairman, I have a great number of questions about the initiative that I hope we will address at this and subsequent hearings, but I won't list them all right now. Instead, I just will close by saying that we are being given the opportunity to construct an exciting and productive future for our nation's civil space program. We owe it to NASA and to the American taxpayers to take the time to get it right.

Thank you, and I yield back my time.

[The prepared statement of Mr. Lampson follows:]

PREPARED STATEMENT OF REPRESENTATIVE NICK LAMPSON

I welcome the President's decision to put forth an exploration agenda, and I look forward to working with him to achieve its goals. I think space exploration brings out the best in us as a people. That said, my colleagues and I need to be convinced that the implementation plan laid out by NASA is in fact both credible and sustainable before I can give it my unreserved support.

We will do no favor to the dedicated men and women of NASA if we fail to ask the tough questions about the President's initiative. For example, what will be the impact of the President's plan on NASA's other programs? I agree with my colleague Mr. Gordon—I am not prepared to do damage to NASA's other important activities in order to make this new plan fit within the President's budget.

Those who know me know that I am an ardent supporter of NASA's human space flight program and of the good work done at the Johnson Space Center. Human space flight is an important part of our nation's overall space effort, and it has delivered significant technological and other benefits to our citizens over the years. But it is only one of NASA's missions.

Recently, law enforcement officials used video imaging technology to identify the suspect in the tragic abduction and murder of the young girl in Florida. What you may not know is that technology was first developed by two NASA employees—one a solar physicist and the other an atmospheric scientist—to assist them in their research activities. It is a poignant but important example of the ways in which our investments in all areas of the space program can serve the broader needs of our society.

As you know, the House recently passed NASA Workforce legislation to improve NASA's ability to attract and retain the best and the brightest. What message will we send if we now embrace an exploration plan that tells a range of dedicated NASA employees: "thanks for your hard work, but we now need your budget for our new initiative."

It seems to me that the President needs to propose funding adequate to do the job right, or NASA regrettably will have to scale back its aspirations. My own strong

preference is that the President provide the funding needed to do the job right. But fundamentally, I don't want to put the NASA employees in the situation of once again trying to fit ten pounds of new tasks into a five-pound budgetary sack. Mr. Chairman, I have a great number of questions about the initiative that I hope we will address at this and subsequent hearings. We owe it to NASA and the American taxpayers to take the time to get it right.

Chairman BOEHLERT. Thank you very much, Mr. Lampson. I am particularly pleased that you mentioned the successful effort on the part of this committee to pass the NASA Restructuring Act, because that will enable Administrator O'Keefe, and others associated with that very important agency, to retain the existing stars on the horizon and to attract the new ones to that lexicon. So I am very pleased with that.

With that, let me say how pleased we are to have with us two very distinguished witnesses, who have proven their service to the Nation by their very capable administration of their duties. First, we have the honorable John Marburger, Director of the Office of Science and Technology Policy, affectionately referred to as the President's Science Advisor, Dr. Marburger, and secondly, our good friend, and so are you, Dr. Marburger—our good friend, Sean O'Keefe, the very able Administrator of the National Aeronautics and Space Administration. And gentlemen, you know the drill. We try to condense the opening statements to allow us ample time for thorough questioning, and there are more questions than can possibly be answered in this hearing. This is the first of several. But I am not going to run a clock on you, but at some time, if you get a little bit too loquacious, I will suggest that maybe you stop and permit us to get a word or two in.

[The prepared statement of Dr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

I want to thank Chairman Boehlert for holding this hearing today. The President has outlined an ambitious new vision for the NASA. It is imperative that we fully understand this vision—its costs, benefits and risks—before we implement it. I am pleased that Mr. O'Keefe and Dr. Marburger are here this morning to provide us with a detailed accounting of the mission, how NASA intends to execute it, and how it fits into the current budget realities of NASA and of the Nation in general.

The President's vision of robotic and manned missions to the Moon and Mars would provide NASA with a clear and compelling mission that the agency has lacked for far too long. As with all daring initiatives, the President's vision for NASA poses significant challenges. Enthusiasm for the President's proposal must be tempered by the realities that face us. Completing the International Space Station, developing a new unmanned space vehicle and mounting missions to the Moon and Mars will all take vast amounts of dedication, innovation, effort and money to accomplish.

To be successful, numerous technical problems, including the development of new propulsion and energy sources and improved life-support systems, will need to be solved. NASA will need an educated, dynamic, and vital workforce to overcome these obstacles. We will need to be serious about expanding our math and science education programs so that we have trained and talented scientists and engineers to do this work. I have championed this educational effort for many years, and Congress has been expanding it. However, the President's proposal dramatizes the need to accelerate our efforts to improve math and science education.

In addition to the cost of creating the workforce NASA needs to carry out this mission, the costs of this journey into space in terms of money and human risk are significant hurdles that we must examine carefully before we agree to expand NASA and its mission. Going to the Moon, and especially Mars, is an expensive undertaking. Several estimates place the cost at many hundreds of billions of dollars. This mission is a very long-term commitment—if we are "in for a penny" then we will be "in for a pound," or, if fact, many, many pounds. We need a realistic estimate

of the overall price tag of the mission and what trade-offs in other programs will need to be made, to be certain that we can, and want to, assume the costs.

In addition to the monetary risk, we must remember that sending humans into space is always perilous. Simply landing a probe on Mars has proven difficult—many of the probes have been lost. A human landing would be complicated by its size, life-support issues, radiation, and other health hazards, and the need to actually safely return the crew. We will need to decide if the scientific and exploration value of a human mission outweighs the risks to human health and consider whether robotic missions might be just as valuable, because they can be done at a fraction of the cost.

As a scientist, I fully understand the desire to explore, to discover, and to learn the unknown. I applaud President Bush for his ability and willingness to provide NASA with a compelling and unifying mission that will satisfy our human desire to explore while inspiring our children to reach towards the heavens. I look forward to hearing Mr. O'Keefe's and Dr. Marburger's justification of the mission, its timeline and technical implementation, and its budget.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. I want to thank Administrator O'Keefe and Director Marburger for appearing before our committee to discuss the President's Vision for Space Exploration and the FY05 Budget for NASA. Today's hearing serves as an opportunity for oversight of certain departmental programs. The President recently announced his space exploration initiative which provides much needed long-term goals for our nation's human space flight program. The lack of clear direction has hampered NASA's effectiveness and has kept it from realizing its full potential as the Nation's space agency. That is why my colleagues on the Science Committee and I have been calling for the administration to establish a vision for the space program even before the Space Shuttle *Columbia* tragedy. In light of the President's new initiative, the budget for NASA leaves many significant questions unanswered and Congress needs more specifics as we consider the FY 05 budget request for NASA.

NASA continues to be our gateway to the universe. It is through NASA's efforts that we will understand our planet, our solar system and beyond. NASA's budget should reflect a strong commitment to, and emphasis on, continuing to build the agency's core foundation of aeronautics and aerospace research and development as well as its missions of exploration and discovery to educate and inspire.

While the President's initiative envisions human lunar landings by 2020 and human missions to Mars at some point in the future, I am concerned that no cost estimate has been provided for this new initiative. Further, it is clear from NASA's budget plan that most of the expenses would be incurred after President Bush has left office.

Finally, I am concerned that many important and promising programs, such as the education programs and space station research, would be eliminated or have their funding cut, deferred, or flattened in order to fund the space exploration initiative. While the Administration states this new initiative is affordable under the budgetary plan developed by NASA, NASA's track record on the credibility of its cost estimates over the last several years is at best mixed.

The President's proposal will have a high price tag and it should not come at the cost of our commitment to our children, our veterans, our seniors, and our other important domestic priorities. We currently have over a half-trillion dollar deficit and the case is going to have to be made to this committee and the American people why this proposal should be supported in the face of that deficit.

I welcome our witnesses and look forward to their testimony.

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

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

Mr. Chairman,

Thank you for calling this hearing to discuss the future of NASA's mission in space, and to understand how the President's new budget fits in that picture. NASA is at a great turning point. Our work here today, and in the upcoming months, could determine if in a century, our kids' kids' kids will be exploring Mars, or if they will be walking through a museum, learning about how long, long ago Americans used to boldly explore the heavens.

I would like to join you in welcoming Dr. Marburger and Administrator O'Keefe. I commend them for their work so far, in keeping us informed on the President's new initiative for human-space flight. Successfully crafting the new mission for NASA will take unprecedented cooperation between the Administration, and Congress, and the private sector, and the American people. I thank the gentlemen for coming today. We must keep this dialogue going.

First, I would like to commend the President for articulating his bold new vision for NASA's future. We have much work to do to ensure that we fine tune that plan, to make sure it fits our goals scientifically, meets our responsibilities, and works within our means in a tough economy. Unfortunately, we are in a time of tight budget, due to horrible financial mismanagement by this Administration over the past three years. But space exploration is not about FY05, or even about five-year projections. It is about an ongoing quest that captures people's minds and hearts, drives our technology to the cutting edge, and pushes our economy forward. We cannot afford to abandon progress in space every time we fall on challenging times. If we allow NASA to follow a boom-bust cycle, it will never have a committed workforce with the expertise and experience necessary to do great things.

So, I feel we must move forward boldly, but not so boldly that we allow the program to collapse under its own weight. We must be safe, and we must be prudent in making methodical steps, to the Moon, to Mars, and beyond.

For example, it is exciting to think of building the next generation vehicle, and to retire the Space Shuttle. But if we are on schedule to decommission the Shuttle in 2010, and then fall behind on the schedule to replace it due to shifting budget priorities, we could be caught in a very tough place. We may lose access to the International Space Station that we have invested so much in. We could start losing quality NASA employees to the private sector or to retirement, and lose their institutional memory as well. That could make it very difficult to restart a viable program in the future.

Of course, I am especially interested in how this new mission will affect Johnson Space Center near my district in Houston. As the hub of the manned space program over the years, Houston has so much to offer this new mission. However, instability as old program give way to new, could be detrimental to the space community and the city as a whole.

And finally I am concerned about safety. Since the *Columbia* tragedy, we are all working together to re-focus on safety—improving the NASA safety "culture" as some call it. We still have much work to do on that. We need to make substantial improvement before we turn all of our thoughts to new things.

I look forward to hearing more about the new U.S. vision for space exploration, and the budget to make it happen. Thank you.

Chairman BOEHLERT. With that, I will open with Dr. Marburger.

STATEMENT OF DR. JOHN H. MARBURGER, III, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Dr. MARBURGER. Thank you, Mr. Chairman and Committee Members, for inviting me to discuss the President's vision for space exploration. I believe the Nation's space enterprise will be strengthened by this vision, which will continue a brilliant record of NASA discoveries that have literally changed the way we view the universe. I have prepared a written testimony that is too long for oral presentation but that does contain detailed responses to the questions that you asked in your letter inviting me to testify. And of course, I will be glad to answer any questions about that detailed account, as well as others.

The first issue is the rationale for the President's vision. The President describes this vision as a journey, not a race. And it differs profoundly from the Apollo paradigm of a single, massive project requiring a large budget spike and an aggressive schedule. In this new vision, milestones are established to guide planning on a series of discreet and mutually reinforcing projects whose aim at

each step is to reduce the cost and the risk of all subsequent missions.

There are certain technical facts about space exploration that seem to be ignored in much of the public commentary, and I describe these briefly in my written testimony, but the President's new paradigm takes these new facts seriously, balancing robotic and human roles in dealing with them and mandates a step-by-step approach to address risks and costs within a steady and realistic flow of resources. Regarding human exploration, the President's vision implies a fundamental change in ground rules. The idea, in his words, is to "explore space and extend a human presence across our Solar System. . .[making] steady progress: one mission, one voyage, one landing at a time." The emphasis here is on sustained exploration and discovery through all appropriate means at a pace we can afford in terms of risk as well as cost.

This new paradigm also acknowledges the obvious fact that the Moon is the nearest platform beyond low-Earth orbit that can sustain the entire range of activities needed in deep space exploration. It is not just a more remote version of the International Space Station. It has the potential of providing mass for numerous uses in further exploration missions, and therefore significantly reducing future costs. The long-term value of the Moon is not primarily in its direct value to science, but in its value to all future deep space operations.

The second issue is the deliberative process leading up to the President's announcement. I have described this process in my written statement. It was a normal White House policy process in which my staff and I were involved from the beginning, as was NASA and Administrator O'Keefe. An extensive literature with many analyses and reports exists on space exploration. I would describe the process as taking place in an information-rich environment. And I would be glad to answer any further questions on process that—Sean and I have sat through a lot of meetings and we can talk about it, but it—there was nothing particularly unusual about this process.

The third issue is the question of the science benefits of the vision. People have referred to that in the opening statements. The President's new paradigm will open up new opportunities to explore and understand the cosmos. Further major advances in understanding the Solar System and the universe, beyond what is now technically possible, will require much more complex operations in space or on the surface of Solar System objects: moons, and planets, and asteroids. These would involve high power instrumentation, large area and long-duration investigation of multiple planetary bodies, and the possible assembly of sophisticated observatories in space or on the surface of other planets. Such complex missions are not possible today for several reasons that are detailed in my written testimony. These reasons are interrelated, and overcoming them systematically will build the backbone for a robust exploration agenda.

Related to this issue is a sequence of enabling initiatives associated with the vision. Once again, there are several important enabling initiatives that are outlined in the President's vision, and I urge you to read the more detailed analysis in my written testi-

mony for each one of these components. I will just name topics that are addressed in my written testimony: the International Space Station, what are we going to do with that; the Moon, why the Moon, what is it that we plan to get out of being on the Moon; the role of robotics; power; and communications capabilities. These are all—there is a technical basis for the choice of emphasis on these topics, and I will be glad to respond to questions about it.

Let me take a little bit more time in my oral remarks to discuss the next issue, which is the impact on existing science activities. That is of immediate importance to many Committee Members. Much of the $11 billion that are reprioritized within the fiscal year 2005 to 2009 budgets comes from discontinuing the launch technology program and savings derived from Shuttle retirement and reprioritization of research on the International Space Station.

In this budget, space science continues to be robust. The vision specifically calls for a new series of robotic exploration missions to the Moon and Mars. The outer planets continue to be a research priority with the Jupiter Icy Moons Orbiter, JIMO, and a mission to Pluto also included.

The Sun-Earth Connection research also remains a priority. Despite the stretch-out of the Solar Terrestrial Probes awards, this program, and all others in NASA's Sun-Earth Connection theme, are scheduled to continue.

A whole new generation of space observatories is being planned. The fiscal year 2005 budget maintains the Webb telescope's scheduled 2011 launch date. Other observatory missions are described in the written version of my testimony. I will say more, at the end of my remarks, about the Hubble telescope.

NASA's Earth Science Enterprise has been, and will continue to be, the largest contributor to the interagency Climate Change Science Program.

The President's fiscal year 2005 budget supports the NASA Aeronautics Blueprint with a request for $919 billion. This maintains the funding level for aeronautics that was in the President's 2004 budget plan. I will say, the presence of fiscal year 2004 earmarks in the budget numbers creates the impression that reductions have been made to content in this program, which is not the case. We are committed to aeronautics, and NASA has created a new enterprise specifically focused on aeronautics within its administrative structure.

The technology development necessary to execute and implement the President's vision will accelerate advances in robotics, autonomous, and fault tolerant systems, human-machine interface, materials, life support systems, and spur novel applications of nanotechnology and micro-devices.

And finally, a framework and a vision for a sustainable exploration, coupled with intellectually stimulating problems, is a powerful asset in our continuing campaign to spark interest in science and technology among young people.

Mr. Chairman, this vision opens up a new era of space exploration. It articulates the purpose for humans in space, and it is good for science.

Now I would like to take a few minutes in the remaining portion of my testimony to go into the technical issues related to the Hubble Space Telescope. You asked——

Chairman BOEHLERT. By all means, do so and ignore the red light, but we are just keeping it on as a guide so that we can focus our attention.

Dr. MARBURGER. Thank you.

You did ask me some specific questions about the Hubble Space Telescope, and there is a longer version of these comments in my testimony.

First of all, let me say that the decision to cancel the SM–4 servicing mission to the Hubble was based on NASA's safety assessment and recommendations made by the *Columbia* Accident Investigation Board. I fully support NASA's concerns about safety, and I support the Administrator's action in asking Admiral Gehman to review this matter and offer his unique perspective.

Now as to the Hubble's importance, the authors of a 2001 National Research Council report said, and I quote, "The Hubble Space Telescope has arguably had a greater impact on astronomy than any instrument since the original astronomical telescope of Galileo."

In the 14 years since the Hubble was launched, however—and I go into many of the discoveries and the assets that Hubble brings in my written testimony. In the 14 years of its 15-year estimated lifetime it—when it was designed, tremendous progress has been made in improving the quality of ground-based telescopes. Using adaptive optics, ground-based telescopes are now capable of resolution competitive with, and in some cases, better than, the Hubble in its longer wavelengths at near-infrared.

In its assessment of space astronomy, the National Research Council report that I quoted did not recommend new missions in the Hubble wavelength regime for three reasons, and let me quote from their report, 2001 report. This report is known as the most recent decadal survey, a very excellent report the astronomy community compiles periodically to guide its future programs. "First, many of the key science opportunities [in this wavelength regime] are predominately in the infrared." "Second, the IR region has been studied much less than the optical region, so the potential for discovery is much greater." And third, "Much of the important optical astronomy can be done from the ground." The Hubble is an optical telescope, reaching into the near-infrared. The committee wrote its report assuming the SM–4 service mission would take place, but its statements regarding the evolving role of the Hubble relative to other priorities are important in the present discussion about risk versus benefits. I might add that the charter for this hearing incorrectly states that a National Academy panel called for yet another servicing mission beyond SM–4. The panel indicated that the benefits of such a mission would have to be assessed by a review similar to the one that led to the report that I quoted.

If serviced, I have no doubt that the Hubble would continue to provide world-class scientific data and be used to further refine our understanding of the universe. But the safety issues can not be ignored, and they must be considered not only with respect to the Hubble capability, but also the ever-increasing capability of visible

ground-based telescopes combined with the exciting next-generation space observatories now being built.

Thank you, Mr. Chairman, for giving me time to make this statement.

[The prepared statement of Dr. Marburger follows:]

PREPARED STATEMENT OF JOHN H. MARBURGER, III

A New Paradigm for Space Exploration

Thank you for inviting me to discuss the President's vision for space exploration. This committee has long supported strong federal science and technology. We believe the Nation's space enterprise will be strengthened by a new focus that only a long-term vision can provide. With a sustainable, long-term vision, NASA will continue a record of discovery that in recent decades has literally changed the way we view the universe. I look forward to your continued support and to working with this committee to realize this vision for space exploration.

Vision Background and Rationale

Neil Armstrong's first footsteps on the Moon in 1969 inspired wonder and excitement throughout the world. In that moment it seemed the unimaginable had become reality, and a course established for an enterprise in space in which anything was possible. Those first footsteps continue to inspire new generations of young scientists and engineers.

Today we know much more about the difficulties of space exploration by humans or machines, and our thinking about space has evolved with our growing awareness of its costs and hazards. Against the background of that experience, the President has provided a general plan for space exploration that is at once visionary and pragmatic. Described by the President as *"a journey, not a race,"* this plan differs profoundly from the Apollo paradigm of a single massive project requiring a large budget spike and an aggressive schedule. In this new vision, milestones are established to guide planning on a series of discrete and mutually reinforcing projects, whose aim at each step is to reduce the cost and risk of all subsequent missions.

Costs and risks are inherent in space exploration. The costs begin with the need to use rockets with their inherent massive fuel requirements to lift even small payloads away from Earth. The risks come from the hostile space environment, weightlessness, and the need to execute complex operations at immense distances from Earth, with mission durations measured not in weeks or months, but years.

The President's new paradigm takes these facts seriously, balances robotic and human roles in dealing with them, and mandates a step-by-step approach to address the risks and costs within a steady and realistic flow of resources. With respect to human exploration, it implies a fundamental change in ground rules. The idea, in the President's words, is to *"explore space and extend a human presence across our solar system. . .[making] steady progress—one mission, one voyage, one landing at a time."* The emphasis is on sustained exploration and discovery through all appropriate means, at a pace we can afford in terms of risk as well as cost.

The new paradigm also acknowledges the stark fact that the Moon is the nearest platform beyond low Earth orbit that can sustain the entire range of activities one would like to conduct in space. It is not just a more remote version of the International Space Station. It has the potential of providing mass for a variety of uses for further exploration missions, and consequently significantly reducing future costs. Some lunar resources may be valuable for Earth satellite applications. The long-term value of the Moon is not primarily in its direct value to science, but in its value to *all* future deep space operations.

Deliberative Process

My office has been involved from the outset in developing this vision. OSTP, NASA, and most segments of the space community recognized the need for a civilian space vision. This need took on a new sense of urgency on February 1, 2003, when the Shuttle *Columbia* was lost. Starting in spring 2003 a group from the White House, NASA, and other agencies began sorting out the relevant issues. Upon the release of the *Columbia* Accident Investigation Board report, which echoed the need for such a vision, the White House established a formal policy process co-chaired by the National Security Council and the Domestic Policy Council. I was directly involved in providing technical support to the process and I was involved in each of the senior meetings, as was Administrator O'Keefe. My staff was engaged in the

process on a daily basis. In this context, a consensus vision and implementation strategy emerged.

This process occurred in an environment rich with information about space exploration. Numerous reports and analyses, produced over decades, have considered the future of civil space exploration in great detail. Tradeoffs between human and robotic capabilities have been debated, passionate discourses have been written about the ultimate destination—whether it should be the Moon, Mars, or a Lagrangian point, and the ultimate wisdom of committing the resources to set our sights beyond planet Earth. These analyses and inputs were used to inform the discussion and to frame the vision articulated by the President.

Exploration Opportunities

The President's new paradigm will open up new opportunities to explore and understand the cosmos that are not technically possible today. During the first 40 years of NASA's exploration, of the solar system, the available technology and resources have allowed for flyby missions of numerous moons, asteroids, comets, and every planet except Pluto. In a few cases, orbital missions were executed (the Moon, Venus, Mars, Jupiter, and the asteroid Eros) and in even fewer cases, landings were made (the Moon, Venus, and Mars).

During the same period, space observatories have become increasingly more sophisticated, opening up windows of observation that are impossible from the ground. Data from these facilities have transformed our understanding of the formation and evolution of the Universe.

Further major advances in understanding the Solar System and the universe will likely require even more complex operations in space or on the surface of solar system objects. These would involve high power instrumentation, large area and long-duration investigation of multiple planetary bodies, and the possible assembly of sophisticated observatories.

Such complex missions are not possible today for several reasons including: the small payload mass we can affordably send into deep space; limitations in power due to decreasing solar flux at high latitudes on near planets or deeper into space; slow communications data rates to Earth; and the challenge of programming autonomous missions and controlling operations from Earth given the large time delays imposed by the finite speed of light.

These "infrastructure" issues are inter-related and their resolution will provide the backbone for a robust exploration agenda—an agenda that allows for close-in examination, the ability to touch the item under scrutiny, and the evaluation of large area and long-term trends. The President's vision also establishes a balance between robots and humans, using the strengths of each to optimize the complex missions.

The President's vision and its budget call for the deliberate development of the capabilities needed to open up the Universe to increased scrutiny. It will create new transportation options for both robots and humans, harness the natural resources found in space to foster sustainability, develop robust high power systems, improve communications, and build vastly more capable robots and improved robotic-human interfaces.

Near-Term Science and Technology Enablers

There are several important enabling initiatives outlined in the vision:

International Space Station (ISS): The ISS provides an important laboratory for understanding the effects of the hostile space environment on human health and well being. The emphasis of the U.S. research on the Station will be refocused to support space exploration goals, including counteracting the impact of the space environment on human health and advanced life support systems. The U.S. research on the ISS will leverage terrestrial laboratory work to develop a more complete understanding of the effects of the space environment on human physiology and to develop countermeasures.

Moon: We will return to the Moon as a first step to opening the Solar System to further human exploration, including Mars missions. The first missions will be robotic and will provide a more detailed assessment of the material composition and variability across the lunar surface and will help to resolve uncertainty in our understanding of the formation and early geological history and subsequent evolution of the Earth and the other inner planets. Furthermore, the lunar missions will demonstrate our ability to live and work on another world. Apollo demonstrated that we could transport humans to the Moon, land, and return safely. The six Apollo flights that landed on the Moon spent a sum total of less than 300 hours on the lunar surface (less than 13 days). While we have demonstrated in the past that we can land on the Moon and return safely to Earth, we must now demonstrate that we can build and operate an infrastructure capable of supporting life for many

months in an alien, inhospitable environment far from home. Furthermore, as previously described, the Moon is potentially a rich source of materials. Previous space commissions and studies have emphasized that extracted resources from the lunar surface can greatly enhance our ability to explore the solar system by refueling rockets; providing metals, ceramics, and other materials; and sustaining more cost-effective access to Mars and other worlds by launching materials from the Moon rather than from the Earth's surface.

Robotics: The vision specifically calls for robotic missions to serve as the trailblazers. As amply demonstrated by the Mars Exploration Rovers "Spirit" and "Opportunity" and the armada of space observatories and planetary probes, robots serve us well and provide excellent science returns. But the President's vision recognizes the need for human oversight of a next phase of much more complicated missions than is achievable with today's remote sensing or limited rovers. Enabling this new paradigm of exploration will require more sophisticated robotic capabilities and an exquisite interface between robots and humans.

Power and Communications: The next steps in exploration, which include *in situ* robotic operations, sample return missions, and human presence, will require much greater communication bandwidth and power systems. NASA is currently pushing optical communications for planetary missions that would in principle improve data transfer rates to Earth by orders of magnitude. Imagine the advantage, not to mention the excitement, of watching high resolution video—rather than today's still pictures—from a rover traveling through the Martian landscape. Also integral to the exploration vision is enabling much greater power to operate the instruments and tools. Advanced nuclear power systems being developed have the capability to operate at all latitudes on Mars and deeper in the Solar System where the solar flux is feeble.

Maintaining Strong Science

The changes to the NASA budget reflect the new priorities derived from the vision as well as the fiscal realities. Much of the $11 billion reprioritized within the FY 2005–FY 2009 budget comes from discontinuing the launch technology program, savings derived from the Shuttle retirement, and reprioritizing research on the International Space Station. The rest of the savings comes from slowing down a few missions and keeping the spending rate constant for other programs.

In this budget, Space Science continues to be robust. The vision specifically calls for a new series of robotic exploration missions to the Moon and Mars. The outer planets will continue to be a research priority with the Jupiter Icy Moons Orbiter (JIMO)—designed for long-duration, in-depth study of three Jovian moons that appear to contain significant water ice. And the budget includes a mission to Pluto—the only planet in our Solar System left to be visited by robotic probes.

The Sun-Earth Connection research remains important to NASA and the Nation. Despite the stretch-out of the Solar Terrestrial Probes awards, this program—and all others in NASA's Sun-Earth Connection theme—is scheduled to continue. The Sun-Earth Connection research budget rises by $17 million in 2005 from the 2004 level and will remain at roughly the $200 million level for the next several years. The 2005 budget therefore enables NASA to continue to pursue its goals in solar science. In addition, Sun-Earth Connection funding is expected to grow from $746 million in 2005 to $1.05 billion in 2009, providing for the ability to begin new and exciting major solar and space physics missions.

Observatories that probe the evolution of our universe and the matter within it are among the most important instruments in science. Building upon the success of missions like the Hubble, Spitzer, WMAP, and others, a whole new generation of space observatories is being planned, each pushing the frontiers of new wavelengths and resolutions to peer back in time toward the origins of the universe; observe potentially cataclysmic events; and to identify and study extra-solar planetary systems. The FY 2005 budget maintains the Webb telescope's scheduled 2011 launch date. Funding is provided to cover launch delays to the Gamma-ray Large Area Space Telescope (GLAST), the Gravity Probe B, Swift and Herschel-Planck. Pushing the frontier of space observations even further are Con-X and the Laser Interferometer Space Antenna (LISA) which are maintained in the budget but slowed down slightly, which will help NASA to retire some of the technical risk associated with these pioneering missions.

NASA's Earth Science Enterprise has been, and will continue to be, the largest contributor to the interagency Climate Change Science Program (CCSP). The President's Budget requests nearly $1.5 billion for NASA's Earth Science programs. These funds support new missions to measure ocean salinity, assess carbon dioxide concentration, and monitor aerosol concentrations in-line with the Climate Change Strategic Plan released this past summer. In addition, funds are provided to ensure

the continuity of Landsat data as well as test key sensors on the next-generation of operational Polar orbiting satellites, both of which are important components of our Earth observing infrastructure. In a few instances missions are deferred and/or canceled where the absence of specific data sets would not cause undue harm to scientific progress.

The President's FY 2005 budget supports the NASA Aeronautics Blueprint with a request for $919.2 M. This maintains the funding level for Aeronautics that was in the President's FY 2004 budget plan. The presence of FY 2004 earmarks in the budget numbers creates the impression that reductions have been made to content, which is not the case. The Blueprint identifies challenges facing aviation today and describes a vision of technology advances that will help solve these challenges. These advances will also create a whole new level of system performance and revolutionize civil and military aviation. The proposed FY 2005 budget request includes the development of the highest priority (safety/security, noise, and emissions) technologies and directly supports the vision espoused by the Blueprint. To further emphasize the priority of Aeronautics, a new NASA enterprise specifically focused on Aeronautics has been created.

Benefits to Science and Technology

In addition to the programs described above, two additional benefits for science and technology are anticipated from the President's vision. First, the technology development necessary to carry out this vision will accelerate advances in robotics, autonomous and fault tolerant systems, human-machine interface, materials, life support systems, and spur novel applications of nanotechnology and micro-devices. All of these advances, while pushing the frontiers of space, are likely to spur new industries and applications that will improve life on Earth.

Second, articulating the human journey into the cosmos, with clear and challenging milestones, will inspire future generations of young people to study math, science, and engineering. A framework and a vision for a *sustainable* exploration, coupled with intellectually stimulating problems, is a substantial asset in the continuing campaign to spark interest in science and technology in each new generation.

Conclusion

This vision has consequences. It implies that we optimize not for a single mission but for the steady accumulation of technologies and capabilities that provide a base for multiple operations. It emphasizes the role of robotics, of ground-based research, and of system thinking. And it places the International Space Station in a larger context of preparation for the journey of exploration.

The vision articulates the purpose for humans in space. We have a vigorous and highly productive program of non-human space operations for scientific, military, and commercial purposes. These "robotic" missions have their own strong justification, and will contribute to the achievement of the vision for humans. The philosophy of going step by step, preparing for the future on a broad front, introduces human capabilities only as appropriate, keeping in mind that the ultimate goal is to permit humans to operate routinely on missions where they are needed.

The vision is good for science. Enabling this vision will lead to a greater understanding of our place in the universe, the history of the solar system, and push technology on many fronts that are important to the economic security of this Nation. It will also open up new possibilities for future science missions that have more aggressive goals. And it prioritizes and maintains a healthy portfolio of research in space and aeronautics.

Hubble Space Telescope

In your invitation to testify at today's hearing you asked me to describe the contributions to science made by the Hubble Space Telescope and to assess what would be lost if the Hubble ceased to function earlier than had been planned. And you asked how to weigh these losses against the potential benefits of other activities under the new initiative.

Let me start by stating clearly my understanding that the decision to cancel the SM–4 servicing mission to the Hubble Space Telescope was based upon NASA's assessment of the safety and recommendations made by the *Columbia* Accident Investigation Board. We fully support NASA's concerns about safety and we support the Administrator's action in asking Admiral Gehman to review this matter and offer his unique perspective.

Since its launch in 1990 (and subsequent repair mission), "the Hubble" has provided spectacular data that has improved our understanding of the cosmos. As the authors of the 2001 National Research Council *"Astronomy and Astrophysics in the New Millennium"* put it "The Hubble Space Telescope has arguably had a greater

impact on astronomy than any instrument since the original astronomical telescope of Galileo." The Hubble was launched with a planned 15 year mission and assumed service missions approximately every three years. Over the past decade, servicing missions have made repairs, upgraded instruments, and re-boosted the telescope to ensure a continuing stream of valuable data. The SM–4 mission was designed to replace the gyros that stabilize the telescope, repair some thermal insulation, replace the Fine Guidance Sensor, replace the batteries, and to install two new instruments (Cosmic Origins Spectrograph and Wide Field Camera-3). It was estimated that the servicing mission would have added 4–5 years of life to the Hubble.

In the 14 years since Hubble was launched, tremendous progress has been made in improving the quality of ground based telescopes. Using adaptive optics—that is compensating for atmospheric turbulence which degrades the resolution of the image—ground based telescopes are now capable of resolution competitive with, and in some instances better than, the Hubble in the longer wavelengths (near-infrared)—albeit for objects with good contrast and over smaller fields-of-view. Over the next few years, advanced adaptive optics techniques are being planned for the next generation of ground based observatories, improving both the resolution and fields of view.

In its assessment of ultraviolet and optical astronomy from space, the National Research Council report did not recommend new missions in the Hubble wavelength regime for three reasons: "First, many of the key science opportunities [in this regime] are predominantly in the infra-red" (the wavelength region covered by the recently launched Spitzer telescope). "Second, the IR region has been studied much less than the optical region, so the potential for discovery is much greater. [Third] much of the important optical astronomy can be done from the ground." The committee wrote its report assuming the SM–4 service mission would take place, but its statements regarding the evolving role of the Hubble relative to other priorities are important in the present discussion about risk versus benefits.

There are some things the Hubble can do that ground based telescopes cannot. It can stare at select regions of the sky for extremely long periods of time. It can return to anyplace in the sky over time and add up or 'stack' exposures. Ground-based observatories can do this same 'stacking,' but to a much more limited extent because of the variations introduced by the atmosphere. In the vast majority of cases ground-based imaging observations are limited to a single night's length. Where they overlap in wavelength coverage, larger ground-based telescopes collect light faster than Hubble so similar science can be done in less time.

The next generation Webb Space Telescope—Hubble's replacement—is being designed with about six times the collecting area, which should allow for study of fainter objects. The Webb is also being designed to be optimized in wavelengths that are not accessible from the ground, providing data that can not be collected from a platform other than one in space.

If it is serviced, I have no doubt that the Hubble would continue to provide world-class scientific data and be used to further refine our understanding of the Universe. But the safety issues can not be ignored, and they must be considered not only with respect to the Hubble capability, but also the ever increasing capability of visible ground-based telescopes combined with the exciting next-generation space observatories being built.

As stated earlier, I commend the NASA Administrator for taking an objective look at this problem and for soliciting the review by Admiral Gehman.

BIOGRAPHY FOR JOHN H. MARBURGER, III

John H. Marburger, III, Science Adviser to the President and Director of the Office of Science and Technology Policy, was born on Staten Island, N.Y., grew up in Maryland near Washington, D.C., and attended Princeton University (B.A., Physics 1962) and Stanford University (Ph.D., Applied Physics 1967). Before his appointment in the Executive Office of the President, he served as Director of Brookhaven National Laboratory from 1998, and as the third President of the State University of New York at Stony Brook (1980–1994). He came to Long Island in 1980 from the University of Southern California where he had been a Professor of Physics and Electrical Engineering, serving as Physics Department Chairman and Dean of the College of Letters, Arts and Sciences in the 1970's. In the fall of 1994 he returned to the faculty at Stony Brook, teaching and doing research in optical science as a University Professor. Three years later he became President of Brookhaven Science Associates, a partnership between the university and Battelle Memorial Institute that competed for and won the contract to operate Brookhaven National Laboratory.

While at the University of Southern California, Marburger contributed to the rapidly growing field of nonlinear optics, a subject created by the invention of the laser

in 1960. He developed theory for various laser phenomena and was a co-founder of the University of Southern California's Center for Laser Studies. His teaching activities included "Frontiers of Electronics," a series of educational programs on CBS television.

Marburger's presidency at Stony Brook coincided with the opening and growth of University Hospital and the development of the biological sciences as a major strength of the university. During the 1980's federally sponsored scientific research at Stony Brook grew to exceed that of any other public university in the northeastern United States.

During his presidency, Marburger served on numerous boards and committees, including chairmanship of the governor's commission on the Shoreham Nuclear Power facility, and chairmanship of the 80 campus "Universities Research Association" which operates Fermi National Accelerator Laboratory near Chicago. He served as a trustee of Princeton University and many other organizations. He also chaired the highly successful 1991/92 Long Island United Way campaign.

As a public spirited scientist-administrator, Marburger has served local, State and Federal governments in a variety of capacities. He is credited with bringing an open, reasoned approach to contentious issues where science intersects with the needs and concerns of society. His strong leadership of Brookhaven National Laboratory following a series of environmental and management crises is widely acknowledged to have won back the confidence and support of the community while preserving the Laboratory's record of outstanding science.

Chairman BOEHLERT. Thank you very much, Dr. Marburger. And we have given you a little more than double the normal time for opening, and we would accord Administrator O'Keefe the same courtesy, because it is such an important aspect. But I would hope that we could all avoid what I refer to as the schmoozing aspect of these hearings. I don't want my colleagues in the Committee thanking me making this hearing possible. Circumstances make it necessary. And we know we have good working—solid working relationships, so we want to, as much as——

Mr. ROHRABACHER. Mr. Chairman, I would like to thank you for saying that. That is a——

Chairman BOEHLERT. And with that, we don't have to remind everyone of the solid working relationship we have with Administrator O'Keefe and the agency and with Dr. Marburger and the White House crew. We are interested in as much factual content in this first of many hearings as we can possibly get.

With that, let me introduce my good friend, Sean O'Keefe.

STATEMENT OF MR. SEAN O'KEEFE, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. O'KEEFE. Thank you, Mr. Chairman and Members of the Committee. I appreciate the opportunity to be here. And to summarize, I think in a slightly different direction here than Dr. Marburger has done, I think he gave a very comprehensive review of the overall strategy, and I will just try to touch on a couple of highlights that augment that as well.

First and foremost, last August 26, the *Columbia* Accident Investigation Board, I think very pointedly, observed the absence of strategy and national goals as being a contributing factor in the space policy drift, as they referred to it, over the past, what they call, three decades. It was an interagency process that Dr. Marburger described, and as we go into in some detail in the prepared statement, to address and accelerate those very questions and to examine this point very specifically.

The Congress and certainly in multiple hearings, as well—on both sides of the Hill, as well as countless editorial pages, call for

the President to offer a vision. Well, on January 14, the President did just that. It is a journey, not a race. That was his primary phrase, and that was the function, I think, that he was really trying to drive home as a long-term objective. So this is not a program for which there can be discreet elements that you tote up and determine what the ultimate consequence is; this is something that over a longer period of time, we can assess, and must assess, progress as we approach this journey, not toward a singular objective.

It is not a crash program. It is not something intended to be a take everything out and put everything you have got toward it in order to achieve single-point destination objectives. It is a long-term set of objectives that I think Dr. Marburger touched on very extensively.

It is a deliberate focus on lunar, Mars, and beyond objectives. The exploration will be informed by the scientific objectives. That is a primary function of exploration informed by the science as we move forward. It is a deliberate, focused approach to knock down the technology obstacles and hurdles necessary to achieve each goal in turn. The strategy of a stepping-stone approach is to build on successes, as realized, not to anticipate inventions along the way for the success of each stage. Instead, as successes materialize, then you adapt the plans and you adjust them necessary to accomplish the longer-term goals that the President has laid out.

It is fiscally responsible. The President's budget as $16.2 billion, and rising in the five year plan, is well within the President's fiscal policy to contain discretionary spending below four percent growth and to cut the deficit in half within five years. All of that has been accommodated in the proposal that the President submitted on February 2.

It is achievable, it is ambitious, it is focused, and it is affordable. The vision document that all of you have before you is the bridge, if you will, between the President's statement, his policy directive, and the budget that is in place. And we have put that together as a means to try to describe the entire approach on how this journey will play out in degrees and by chapter.

There is no massive commitment today that will be expected to be paid for by a future Congress, and each step in every interval along the way, the President and the Congress, annually, will have an opportunity to evaluate that progress and consider proposals for how that next chapter will proceed. This is the overall game plan. It is the objectives of what has been articulated, but in terms of how it is successively taken on is an annual matter of review, and there is no commitment that is being requested today that commits to a large balloon note in the future. Each of it is progressively developed.

As mentioned earlier, too, as well, the President developed a commission, appointed them, they had their first hearings in the last couple of days here. He appointed them just last week. Secretary Pete Aldridge is Chairman of that commission: nine distinguished members of the academic industry and former public service communities to help guide how that strategy will be carried out.

And finally, Mr. Chairman, if I could offer the observation, I guess, that has been included in several editorial pages as well is

the divergence or disparate views within the public condition right now. The public interest is there. I offer to you just an anecdote of the last 40 days; the NASA website has received six billion hits. Six billion hits. That involves 47 unique different visitors—47 million, excuse me. So as a consequence, it is not only—it is not 47 people hitting the same button at the same time to achieve six billion hits. It is 47 million people who are, in turn, then returning repetitively to the website in the course of that time. Over the span of this 40-day period, that is more than twice the total number of hits we have received all of last year. All of last year was four times that which we had ever received before. So as a consequence, the interest level with what is going on and what is involved is extremely high. It involves 430 million page views that are involved in this. It is effectively the equivalent of distributing all of what is contained in the Library of Congress 7½ times over the course of 40 days. That is what has been delivered through the website alone.

It also includes a wide range if disparate kinds of interests involved. There are more than 1,000 schools in the United States and universities, which have accessed the web page over the span of this time. It includes not only K through 12 programs, but also university efforts.

The sections that are being hit, it is not isolated to one area. It includes not only the Mars rovers updates, but also the kids' section, which is up five times, students' section, which is up three times. Educators are going to this at a factor of three higher than they have ever gone to it before. And so as a prospect of this—or a consequence of it, the interest level across everything we are engaged in is pretty high.

Just to give you a quick flavor of what it is they are looking at, let me ask—there are a couple of charts, I think, before you, but I will give it to you in a graphic as well, and they are very, very brief.

[Slide.]

Certainly, the immediate image or interests are on the success of the two Mars rovers. This first image is a color image taken by the panoramic camera aboard Spirit showing the Adirondack, which was, I think, appropriately named, given its formation.

[Slide.]

The next is a medium resolution version of a 360-degree view of the Martian surface taken aboard Spirit, in its camera.

[Slide.]

The next is a drag mark that was made by the Spirit as it moved off of the deflated area and moved on to the area referred to as "Magic Carpet" as it moved along.

[Slide.]

The next series is Opportunity. It is a picture taken soon after Opportunity landed, showing the interior of the crater, which it is now exploring.

[Slide.]

The next is an image by Opportunity's navigation camera showing an overhead perspective of the rover itself and how it initially landed at that point on the *Challenger* Memorial Station location.

[Slide.]

And finally, we have a Martian Coast Guard from the panoramic camera of Opportunity showing the Martian landscape southwest of the rover. This is the area they are really examining with great detail as it works across that.

[Slide.]

And a final image of what is also being struck several times is that of the Spitzer Space Telescope. This past December, two months ago, we—as Spitzer became operational and observes the cosmos in an infrared capacity with unprecedented sensitivity, exactly as Dr. Marburger described. And the comparative images you see here is one versus—in the smaller inset, is what visible light would otherwise provide. The one to the right, in the larger image, is what Spitzer has provided as a consequence of the infrared capability that is now operational and being accessed multi-million times as a consequence of availability on the website today.

With that, Mr. Chairman, I thank you for the opportunity to testify, and I look forward to your questions, sir.

[The prepared statement of Mr. O'Keefe follows:]

PREPARED STATEMENT OF SEAN O'KEEFE

Mr. Chairman and Members of the Committee, thank you for this opportunity to appear today to discuss NASA's FY 2005 budget request. On January 14th, the President visited NASA Headquarters and announced his Vision for U.S. Space Exploration. In his address, the President presented a vision that is bold and forward-thinking, yet practical and responsible—one that explores answers to longstanding questions of importance to science and society and will develop revolutionary technologies and capabilities for the future, while maintaining good stewardship of taxpayer dollars.

The vision forms the basis of the new U.S. space exploration policy, "A Renewed Spirit of Discovery." (See charter, p. 7.) This policy is the product of months of extensive and careful deliberation. The importance of these deliberations increased with the findings of the *Columbia* Accident Investigation Board, which emphasized the importance of setting clear, long-term goals for the Nation's human space flight program. Inputs from Members of this committee and other Members of Congress informed the Administration's deliberations. Many others contributed ideas for the future of the space program. These deliberations were also the basis for formulating the President's FY 2005 Budget request for NASA. A commission will advise NASA on specific issues for implementation of the policy's goals within four months.

Today, I will summarize the President's FY 2005 budget request for NASA, discuss the goals set forth in the new U.S. space exploration policy, walk you through the major implementation elements and their associated budget details, explain the implications of this directive for NASA's organization, and describe what the Nation's future in exploration and discovery will look like in the coming years.

FY 2005 Budget Summary

The President's FY 2005 Budget request for NASA is $16.244 billion, a 5.6 percent increase over FY 2004, as reflected in *Enclosure 1.* The NASA budget request is designed with four key goals in mind:

Compelling—The budget fully supports the U.S. Vision for Space Exploration, and provides for ongoing NASA mission priorities such as Aeronautics and Earth Science.

Affordable—The budget is fiscally responsible and consistent with the Administration's goal of cutting the federal deficit in half within the next five years. NASA's FY 2005 budget will increase by $1 billion over five years, when compared with the President's FY 2004 plan; that is an increase of approximately five percent per year over each of the next three years and approximately one percent for each of the following two years.

Achievable—The budget strategy supporting the vision will not require large balloon payments by future Congresses and Administrations. Unlike previous major civil space initiatives, this approach is intentionally flexible, with investments in sustainable exploration approaches to maintain affordability. After FY 2009, the budget projects that the exploration vision can be implemented within a NASA budget that keeps pace with inflation.

Focused—The budget begins the alignment of NASA's program structure with the exploration vision. We now have the needed compass from which to evaluate our programs and make the needed tough decisions.

Vision Goals

The fundamental goal of this new policy is to advance U.S. scientific, security, and economic interests through a robust space exploration program. In support of this goal, NASA will:

- Implement a sustained and affordable human and robotic program to explore the Solar System and beyond;
- Extend human presence across the Solar System, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;
- Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about destinations for future human exploration; and
- Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

Implementation Elements and Budget Highlights

To achieve these goals, NASA will plan and implement an integrated, long-term robotic and human exploration program, structured with measurable milestones and executed on the basis of available resources, accumulated experience, and technology readiness. The policy envisions the following major implementation elements:

Space Shuttle—NASA will return the Space Shuttle to flight as soon as practical, based on the recommendations of the *Columbia* Accident Investigation Board. The budget includes $4.3 billion for the Space Shuttle, a nine percent increase above FY 2004. Included in this total is an estimated $238 million for Return to Flight (RTF) activities in FY 2005. The RTF activities are under evaluation to confirm the estimated cost and associated out year phasing. The focus of the Space Shuttle will be finishing assembly of the International Space Station (ISS). With its job done, the Space Shuttle will be phased out when assembly of the ISS is complete, planned for the end of the decade. NASA will determine over the next year how best to address the issues associated with the safe retirement of the Space Shuttle fleet.

International Space Station—NASA plans to complete assembly of the International Space Station (ISS) by the end of the decade, including those U.S. components that will ensure our capability to conduct research in support of the new U.S. space exploration goals and those planned and provided by foreign partners. The budget provides $1.9 billion for ISS assembly and operations, a 24 percent increase above FY 2004. This increase forward funds $100 million in reserves to partially restore planned near-term reserve levels following the $200 million Congressional cut to Space Station in FY 2004 and provides $140 million in new funding for transportation services to the Space Station. We will separate, to the maximum extent practical, crew and cargo transportation for both ISS and exploration missions. NASA will acquire ISS crew transport as required and cargo transportation as soon as practical and affordable. NASA envisions that commercial and/or foreign capabilities will provide these services.

NASA anticipates that any adjustments in existing ISS Partner responsibilities as a result of the new U.S. space exploration policy can be accommodated within the existing ISS agreements. The ISS Multilateral Coordination Board is scheduled to meet today to begin the process of coordination within the Partnership on implications to the ISS resulting from the new policy. The Administration is also prepared to address issues associated with obtaining foreign transportation services to the Space Station, including provisions of the Iran Nonproliferation Act, but until the ISS Partnership adopts a specific implementation strategy, it is premature to identify specific issues.

U.S. research activities aboard the ISS will be focused to support the new exploration goals, with an emphasis on understanding how the space environment affects astronaut health and capabilities, and on developing appropriate countermeasures to mitigate health concerns. ISS will also be vital to develop and demonstrate improved life support systems and medical care. Consistent with this focus, the budget provides $343 million, a 61 percent increase above FY 2004, for bioastronautics research to understand and mitigate risks to humans on exploration missions. Over the next year, the Biological and Physical Research Enterprise will conduct a thorough review of all research activities to ensure that they are fully aligned with and supportive of the new exploration vision.

New Space Transportation Capabilities—The budget provides $428 million to begin a new Crew Exploration Vehicle, named Project Constellation, that will provide crew transport for exploration missions beyond low-Earth orbit. The current budget planning is based on formulation concept studies to be conducted in FY 2004, preliminary design activities conducted in FY 2005 and FY 2006, a System Design Review in FY 2005, and a Preliminary Design Review in FY 2006. NASA plans to develop Project Constellation in a step-by-step approach, with an initial unpiloted test flight as early as 2008, followed by tests of progressively more capable designs that provide an operational human-rated capability no later than 2014. Project Constellation may also provide transportation to the Space Station, but its design will be driven by exploration requirements.

NASA does not plan to pursue new Earth-to-orbit transportation capabilities, except where necessary to support unique exploration needs, such as a heavy lift vehicle. The budget discontinues the Space Launch Initiative, although knowledge gained on the Orbital Space Plane will be transferred to Project Constellation.

Lunar Exploration—NASA will undertake lunar exploration and demonstration activities to enable sustained human and robotic exploration of Mars and other destinations in the Solar System. Beginning no later than 2008, NASA plans to launch the first in a series of robotic missions to the Moon to prepare for and support human exploration activities. The budget provides $70 million for these robotic lunar test beds, increasing to $420 million by FY 2009. The policy envisions the first human expedition to the lunar surface as early as 2015, but no later than 2020. These robotic and human missions will further science and demonstrate new approaches, technologies, and systems—including the use of space resources—to support sustained human exploration to Mars and other destinations.

Exploration of Mars—The stunning images we have received from Mars are just the beginning of future Mars exploration. NASA will enhance the ongoing search for water and evidence of life on Mars by pursuing technologies in this decade for advanced science missions to Mars in the next decade. Also starting in the next decade, NASA will launch a dedicated series of robotic missions to Mars that will demonstrate greatly enhanced robotic capabilities and enable future human exploration of the Red Planet. The budget provides $691 million for Mars Exploration, a 16 percent increase over FY 2004, and will double Mars Exploration funding by FY 2009. NASA will conduct human expeditions to Mars and other destinations beyond Earth orbit on the basis of available resources, accumulated experience, and technology readiness.

Other Solar System Exploration—Over the next two decades, NASA will conduct an increasingly capable campaign of robotic exploration across the Solar System. The budget provides $1.2 billion for Solar System Exploration missions to Jupiter's icy moons, to Saturn and its moon Titan, to asteroids and comets, and to other Solar System bodies. These missions will search for evidence of life, help us to understand the history of the Solar System, and search for resources.

Extrasolar Planets—NASA will launch advanced space telescopes that will search for Earth-like planets and habitable environments around other stars. The budget includes $1.1 billion for the Astronomical Search for Origins, a 19 percent increase over FY 2004, to support Hubble Space Telescope operations, the recently launched Spitzer Space Telescope, James Webb Space Telescope development, as well as three future observatories. This funding also supports investments to extend the lifetime of the Hubble Space Telescope to the maximum extent possible without a servicing mission.

Enabling Capabilities—NASA will pursue a number of key capabilities to enable sustainable human and robotic exploration across the Solar System. Among the most important of these capabilities is advanced power and propulsion, and the budget provides $438 million for Project Prometheus to develop these technologies for future robotic and human exploration missions. The budget also includes $636 million in other Human and Robotic Technology funding to pursue sustainable approaches to Solar System exploration, such as reusable and modular systems, prepositioned propellants, space resource utilization, automated systems and robotic networks, and in-space assembly. These technologies will be demonstrated on the ground, in orbit, and on the Moon beginning in this decade and extending into the next to help inform future exploration decisions. The budget projects that funding for these Human and Robotic Technology investments will grow to $1 billion by FY 2009.

The budget also includes innovative opportunities for U.S. industry, academia, and members of the public to help meet the technical challenges inherent in the new

space exploration vision. The budget includes $20 million for the new Centennial Challenges program, which will establish competitions to stimulate innovation in space and aeronautical technologies that can advance the exploration vision and other NASA missions. The budget also provides $10 million for NASA to purchase launch services for its payloads from emerging launch vehicle providers. And as previously mentioned, the budget includes $140 million for Space Station transportation services.

Ongoing Priorities—The budget supports the vision for space exploration, while maintaining NASA commitments in other important roles and missions.

NASA continues its commitment to helping understand our changing global climate. The budget makes NASA the largest contributor to the interagency Climate Change Science Program with $100 million for the Climate Change Research Initiative. The budget includes $560 million for Earth Science research, a seven percent increase above FY 2004, to support research on data from 80 sensors on 18 satellites currently in operation. Work also continues on Earth observation missions in development or formulation, including $141 million (a 36 percent increase from FY 2004) for the National Polar Orbiting Environmental Satellite System Preparatory Project, $42 million for the Landsat Data Continuity Mission, and $240 million (a 37 percent increase from FY 2004) for missions in formulation, such as the Orbiting Carbon Observatory, Aquarius and Hydros.

NASA maintains planned Aeronautics Technology investments to improve our nation's air system. The budget includes: $188 million, a four percent increase above FY 2004, for technology to reduce aircraft accidents and improve the security of our nation's aviation system against terrorist threats; $72 million, an 11 percent increase above FY 2004, for technology to reduce aircraft noise and improve the quality of life for residents living near airports; $209 million for technology to reduce aircraft emissions and improve environmental quality; and $154 million for technologies to increase air system capacity and reduce delays in the Nation's airports.

NASA will continue to make fundamental advances in our knowledge of the Sun and the Universe. The budget provides $746 million for Sun-Earth Connection missions, including the Solar Dynamics Observatory and the Solar-Terrestrial Relations Observatory. The budget also provides $378 million for Structure and Evolution of the Universe missions, including the Chandra X-ray Observatory and three major missions currently under development.

NASA also maintains its role in science, engineering and math education. The budget includes $10 million for the newly authorized Science and Technology Scholarship program, which will help attract the Nation's best college students to NASA science and engineering careers. The budget also provides $14 million for the NASA Explorer Schools, which seeks to attract students to mathematics and science during the critical middle school years. The Explorer Schools program is entering its third phase and will be selecting 50 new schools for a total of 150 participating schools.

Management of Human Capital Facilities and Institution—NASA has earned the distinction of being the only federal agency to earn top grades for the Human Capital and Budget and Performance Integration initiatives under the President's Management Agenda. Congress recently passed the NASA Workforce Flexibility Act. NASA is grateful for the hard work of this committee in shaping this legislation to provide necessary flexibilities to better manage the NASA workforce. These flexibilities will be critical to implementing the exploration vision. The budget includes $25 million in FY 2005 to begin to address critical workforce skill and aging issues. NASA ratings have also improved in the Competitive Sourcing and E-Government initiatives, resulting in more total improvements than any other agency. Although we received a disclaimed opinion on our recent audit statement, we are determined in pursuing the right path in Financial Management in bringing on a new financial system that will standardize accounting across the Agency and provide the necessary tools for improved program management. NASA remains committed to management excellence and believes it is essential to implementing the new exploration vision.

The budget includes funding for critical institutional capabilities, including $77 million for the NASA Engineering Safety Center and $27 million for Independent Verification and Validation. The budget also provides $307 million, a $41 million increase versus FY 2004, for facilities maintenance.

Organizing for Exploration

To successfully execute the exploration vision, NASA will re-focus its organization, create new offices, align ongoing programs, experiment with new ways of doing business, and tap the great innovative and creative talents of our nation.

The President has issued an Executive Order creating a commission of private and public sector experts to advise on these issues. Former Undersecretary of Defense and Secretary of the Air Force, Pete Aldridge, is Chair of the Commission. The President has named eight other commissioners to join Mr. Aldridge. The commission will issue its report within four months of its first meeting, which is scheduled for February 11, 2004.

Immediately following the President's speech, we established an Exploration Systems Enterprise, which will have responsibility for developing the Crew Exploration Vehicle and other exploration systems and technologies. Retired U.S. Navy Rear Admiral Craig Steidle, former manager of the Defense Department's Joint Strike Fighter Program, is heading this new organization. Relevant programs of the Aerospace Technology, Space Science, and Space Flight enterprises are being transferred to the Exploration Systems Enterprise. The Aerospace Technology Enterprise has been renamed the Aeronautics Enterprise to reflect its new focus.

As human explorers prepare to join their robotic counterparts, coordination and integration will increase. The Exploration Systems Enterprise will work closely with the Space Science Enterprise to use the Moon to demonstrate new approaches, technologies, and systems to support sustained human exploration. NASA's Space Science Enterprise will have responsibility for implementing early robotic testbeds on the Moon and Mars and will also demonstrate other key exploration technologies—such as advanced power, propulsion, and communications—in missions to Mars and Jupiter's moons. NASA's Space Science Enterprise will eventually integrate human capabilities into exploration planning for Mars and other destinations.

Many other elements of the NASA organization will be focused to support this new direction. NASA's Biological and Physical Research Enterprise will put much greater emphasis on bioastronautics research to enable the human exploration of other worlds. NASA's Office of the Space Architect will be responsible for integrating the exploration activities of NASA's different Enterprises and for maintaining exploration roadmaps and coordinating high-level requirements.

As we move outward into the Solar System, NASA will look for innovative ideas from the private sector and academia to support activities in Earth orbit and future exploration activities beyond. Many of the technical challenges that NASA will face in the coming years will require innovative solutions. In addition to tapping creative thinking within the NASA organization, we will leverage the ideas and expertise resident in the Nation's universities and industry.

In his speech, the President directed NASA to invite other nations to share in the challenges and opportunities of this new era of exploration and discovery, and he directed us to fulfill our standing international commitments. We are discussing the impact of our vision implementation plans on the ISS with our partners, and as I have already indicated we will complete the assembly of the ISS. The President called our future course of exploration "a journey, not a race," and other nations have reacted positively to the President's guidance. Several have already contacted us about joining in this journey. Building on NASA's long history and extensive and close ties with the space and research agencies of other nations, we will actively seek international partners in executing future exploration activities.

NASA will also invigorate its workforce, focus its facilities, and revitalize its field centers. As exploration activities get underway, NASA anticipates planning, reviews, and changes to align and improve its infrastructure. In order to achieve the exploration vision, we will be making decisions on how to best implement new programs. While some of these necessary actions will not be easy, they are essential to achieving the goals of the overall effort before us. I urge you to consider the full context of what we will be proposing rather than any isolated, specific action. Such a perspective will allow us to move forward in implementing the vision.

FY 2003 Accomplishments

Much of the NASA's future ability to achieve the new space exploration vision is predicated on NASA's many previous accomplishments. The most visible NASA successes over the past year are the Spirit and Opportunity rovers currently on Mars. Already, the landscapes imaged by these twin rovers and their initial science returns are hinting at fundamental advances in our understanding of early environmental conditions on Mars and whether Mars was once capable of sustaining water and the development of life.

However, Spirit and Opportunity are not the only recent NASA mission successes. NASA successfully launched four new Space Science missions (including the two Mars rovers), three new Earth Science missions, one new NASA communications relay satellite, and completed two Space Station deployment missions. Missions in operation have also achieved a number of notable successes, including the Stardust mission's successful flight through the tail of Comet Wild-2, initial images from the

recently launched Spitzer Space Telescope, a ten- to 100-fold improvement in Earth's gravity map from the GRACE satellite, the most accurate maps of Earth temperatures to date from the Aqua satellite, and new insights into space weather and solar activity from Sun-Earth Connection missions.

NASA exceeded or met 83 percent of its annual performance goals for FY 2003. Among these accomplishments were demonstrations of new systems to improve air traffic control and to combat aircraft icing, improvements in battery, telescope sensor, and life support technologies, fundamental advances in understanding states of matter from Space Station research, and the implementation of new remote sensing tools for tracking diseases and wild fires.

The Nation's Future in Exploration and Discovery

As the President stated in his speech, we are embarking on a journey, not a race. We begin this journey of exploration and discovery knowing that many years of hard work and sustained effort will be required, yet we can look forward to achieving concrete results in the near-term. The vision makes the needed decisions to secure long-term U.S. space leadership. It provides an exciting set of major milestones with human and robotic missions. It pursues compelling science and cutting-edge technologies. It invites new ideas and innovations for accomplishing this bold, new vision. And it will provide the opportunity for new generations of Americans to explore, innovate, discover and enrich our nation in ways unimaginable today. The President's challenging vision provides unique opportunities for engaging students across the country, "as only NASA can," to enter careers in science, engineering, technology and math.

I sincerely appreciate the forum that the Committee has provided today, and I look forward to responding to your questions.

Enclosure 1

National Aeronautics and Space Administration
President's FY 2005 Budget Request

(Budget authority, $ in millions)	FULL COST						Chapter Number
By Appropriation Account	Est. Conf. Rept.						
By Enterprise	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	
By Theme							
Exploration, Science & Aeronautics	7,830	7,760	7,869	8,320	8,900	9,091	ESA-SUM 1
Space Science	3,971	4,138	4,404	4,906	5,520	5,561	ESA 1
Solar System Exploration	1,316	1,187	1,202	1,300	1,392	1,438	ESA 2
Mars Exploration	595	691	724	944	1,188	1,268	ESA 3
Lunar Exploration		70	135	280	375	420	ESA 4
Astronomical Search for Origins	899	1,067	1,196	1,212	1,182	927	ESA 5
Structure & Evolution of the Universe	406	378	365	382	425	457	ESA 6
Sun-Earth Connections	755	746	781	788	958	1,051	ESA 7
Earth Science	1,613	1,485	1,390	1,368	1,343	1,474	ESA 8
Earth System Science	1,522	1,409	1,313	1,290	1,266	1,397	ESA 9
Earth Science Applications	91	77	77	77	77	77	ESA 10
Biological & Physical Research	985	1,049	950	938	941	944	ESA 11
Biological Sciences Research	368	492	499	496	500	502	ESA 12
Physical Sciences Research	357	300	220	210	210	210	ESA 13
Research Partnerships & Flight Support	260	257	232	232	231	232	ESA 14
Aeronautics*	1,034	919	957	938	926	942	ESA 15
Aeronautics Technology	1,034	919	957	938	926	942	ESA 16
Education Programs	226	169	169	171	170	170	ESA 17
Education Programs	226	169	169	171	170	170	ESA 18
Exploration Capabilities	7,521	8,456	9,104	9,465	9,070	8,911	EC-SUM 1
Exploration Systems*	1,646	1,782	2,579	2,941	2,809	3,313	EC 1
Human & Robotic Technology	679	1,094	1,318	1,317	1,386	1,450	EC 2
Transportation Systems	967	689	1,261	1,624	1,423	1,863	EC 3
Space Flight	5,875	6,674	6,525	6,524	6,261	5,598	EC 4
International Space Station	1,498	1,863	1,764	1,780	1,779	2,115	EC 5
Space Shuttle	3,945	4,319	4,326	4,314	4,027	3,030	EC 6
Space Flight Support	432	492	435	430	456	453	EC 7
Inspector General	27	28	29	30	31	32	IG 1
TOTAL	15,378	16,244	17,002	17,815	18,001	18,034	
Year to year increase		5.6%	4.7%	4.8%	1.0%	0.2%	

*In FY 2004 Aeronautics and Exploration Systems will become separate Enterprises

NOTE: May not add due to rounding

DISCUSSION

BUDGET ASSUMPTIONS AND UNCERTAINTIES

Chairman BOEHLERT. Thank you very much. I would observe that probably most of us in this room are part of the 47 million people who have been excited and have been responsible for those six billion hits on your website. I would also point out that it is the unmanned mission that is exciting the world. And we are here mainly to concentrate on the manned exploration portion of the President's initiative, and that is what we are going to be very specific in addressing.

Mr. O'Keefe, is—a plan as long-range and far-reaching as the Exploration Initiative necessarily has to budget for many items whose costs can not be known with any certainty at this point, what items in the Exploration Initiative are most likely to cost significantly more or less than is currently budgeted? Presumably, the figures used to calculate the budget for the initiative are sort of in the middle range of possible costs. Can you give us the full range of the cost of the initiative? And how likely is it that the initiative can be accomplished for the amount budgeted? A comprehensive question.

Mr. O'KEEFE. Thank you, Mr. Chairman.

First of all, there is no way to put a price tag on a program that is in definition. Again, the objective is to lay out the longer-term objectives, and that is exactly what the President's Directive does. So at each successive stage, there will be a price tag attached to it. Along the way, too, a slight contrast, I think, to your opening comment, this is a combination of both human capacity as well as robotic capacity. That is what is included in the exploration objectives. And all of it is a set of precursor missions that require or demand robotic capabilities beforehand. So the definition of the price tag of those is going to get higher and easier to define as we move along in this particular approach.

In the immediate term, what the plan calls for is an immediate cost of return to flight, of completion of the International Space Station. And on those two, I think we can give you a much greater definition of cost estimate for those accomplishments than on many other elements of it. And then the next stages from there are to develop a Project Constellation, the crew exploration vehicle, which will extend beyond the scope of this decade. And during the course in this time, $6.6 billion has been budgeted and more to follow as we continue that development effort.

Chairman BOEHLERT. But where—I would—so I am assuming middle-range of projections, those are the assumptions we are operating under. But where is the greatest uncertainty? Is it the CEV? Is it the Shuttle? Development? Where is the greatest uncertainty at this juncture?

Mr. O'KEEFE. I personally think that the greatest uncertainty will be the cost to develop power generation of propulsion capacities and over what span of time. Right now we have no means to generate powers or to propel anywhere. It is all based on solar power collection, and that is it. What we are trying to do with Project Prometheus is develop the capacity to propel anywhere, which will get you there faster as well as inform the science oppor-

tunities to generate more power for the science packages involved. That one is the one I think that has got the greatest prospect of uncertainty in terms of what its overall cost is, depending on how you want to size its use. Do you want to apply it just to robotic capabilities? Do you want to include downstream toward the—to power and generate power for and propel a crew exploration vehicle? Those are the—that would be the primary ones, I think, would be the limitations.

Chairman BOEHLERT. Well, is propulsion for the CEV or for later?

Mr. O'KEEFE. Yes, sir; both.

Chairman BOEHLERT. Both?

Mr. O'KEEFE. Yes, sir.

PROGRAM MANAGEMENT AND SUNK COSTS

Chairman BOEHLERT. All right.

The next question: in the past, Congress has often invested so heavily in NASA programs that it seems too late to cancel a program even after it proves to be troubled. We have seen an example of that. What milestones for assessment are built into the major aspects of the Exploration Initiative? At what point should NASA and the Congress re-examine the initiative, particularly CEV development, to determine whether it is appropriate to proceed to completion?

Mr. O'KEEFE. Yes, sir. Thank you for the question. It is an exactly critical one in the sense that the approach we have taken here is a strategy that gives multiple opportunities to assess progress. The approach with the crew exploration vehicle, under Project Constellation, is specifically to develop and use a spiral development technique, which will require the deployment of unmanned capacity on at least a couple of occasions, probably more, between now and the time that we develop a human-rated capability. So what you do is each component, in turn, is launched to demonstrate that success and then build on it.

As that success is evaluated, then you make the decision to move to the next phase thereafter. Along the way, concurrently with that, is also a range of robotic capabilities for lunar exploration as well as potential power generation capability there as well that again will be assessed each, in turn, by mission. And to the extent that there is an adjustment necessary in acceleration or a slowdown of those activities based on the relative success of each of those steps, that is when you make the decision to move off. So there isn't a one-time commitment that will in turn create a balloon note down the road. At each step, you make a judgment about how you progress ahead.

Chairman BOEHLERT. Thank you.

Mr. Gordon.

COST ESTIMATES

Mr. GORDON. Thank you, Mr. Chairman, and I am taking your cue to get down to business.

Let me repeat Mr. Augustine's comments yesterday: "It would be a grave mistake to undertake a major new space objective on the

cheap. To do so, in my opinion, would be an invitation to disaster." Certainly nobody here wants a human disaster or a financial disaster. And I think a financial disaster is getting a quarter of the way down, 20 percent of the way down, 50 percent of the way down the line and saying, "We can't afford this. We are going to do something else." Maybe, you know, there will be some benefits, but we don't want to do that.

And so Mr. O'Keefe, I—this—dollar cost is something that we are all concerned about. I had written you and asked you specifically about that. Your response was, in terms of the cost, it depends, which was pretty much what you said here today. It depends. But we need a benchmark, and I know you can do various things. So if we gave you a benchmark, like going to the Moon by the year 2020, what would be your estimation of that cost?

Mr. O'KEEFE. Well, sir, first and foremost, let me suggest that Augustine's comment yesterday—Mr. Augustine's comment yesterday was also that he had not read any of the details involved in the plan. So I think he quoted that point as well. The second point of exactly how we would return to the Moon by 2020 depends on which components you want to have back into it.

Mr. GORDON. You take any—that is what I am saying. You take any set of components you want. You just take one, get us there, and tell me what it is going to cost.

Mr. O'KEEFE. Okay. Yes, sir. The robotic capability to return to the Moon within this decade should not cost more than $500 to $600 million.

Mr. GORDON. $500 to $600 million?

Mr. O'KEEFE. $500 to $600 million for that robotic capacity——

Mr. GORDON. Just robotic? Okay.

Mr. O'KEEFE [continuing]. To follow through. Then after that, you make a judgment of whether you want to go back with what capabilities.

Mr. GORDON. You go ahead. You just go ahead and lay a benchmark out of what you think would be reasonable, and tell me what it would cost.

Mr. O'KEEFE. I wouldn't want to presume success at any stage. I want to make sure each step along the way——

Mr. GORDON. Well, no, go ahead.

Mr. O'KEEFE [continuing]. And we do this properly.

Mr. GORDON. Just go ahead, you know, and let—go ahead and presume a reasonable course, and tell me what it would cost.

Mr. O'KEEFE. Over the course of this past year, and since February 1, 2003, I have made it a point not to anticipate success beyond the next stage.

Mr. GORDON. Okay. Well, let me put it this way. Dr. Marburger said that you went through a very extensive program, lots of meetings, that it was an environment, as he said, that was information-rich. And you told me that the President was very engaged in this. Now surely the President wouldn't have a pig and a poke. Did the President never ask you what this was going to cost?

Dr. MARBURGER. I think it is important to realize that this is——

Mr. GORDON. Well, that is what I——

Dr. MARBURGER [continuing]. Not a mission——

Mr. GORDON. I have got a limited amount of time. I——

Dr. MARBURGER. This is not a single mission, Apollo-like——
Mr. GORDON. Right.
Dr. MARBURGER [continuing]. Program. And the——
Mr. GORDON. I will take any—again——
Dr. MARBURGER. The fiscal year 2005——
Mr. GORDON. If I could, please——
Dr. MARBURGER. Yes, sir.
Mr. GORDON [continuing]. Because we—I am going to lose time. You know, you take anything you want. You know, just tell me, did the President, in this discussion, at any time, say, "What is this going to cost?"
Dr. MARBURGER. Absolutely.
Mr. GORDON. Okay. And what was your——
Dr. MARBURGER. And the fiscal year 2005——
Mr. GORDON. And what was your answer?
Dr. MARBURGER. The President's budget request has multi-year budget commitments that he is prepared to support that go beyond——
Mr. GORDON. But only five years, isn't it? Does it give anything beyond the five years?
Dr. MARBURGER. Yes, it goes out through 2020——
Mr. GORDON. And are there budget——
Dr. MARBURGER [continuing]. As a matter of fact.
Mr. GORDON [continuing]. Numbers that go with that?
Dr. MARBURGER. And there is a budget profile that goes with that. It is calibrated in, I presume, 2004 dollars.
Mr. GORDON. Okay. So what is it——
Dr. MARBURGER. It goes up——
Mr. GORDON. So what is it going to cost? So—I didn't see——
Dr. MARBURGER. Okay.
Mr. GORDON. So what is the cost by 2020 to go to the Moon?
Dr. MARBURGER. If—you would have to integrate under that curve to find the total cost, but the curve goes up on a line that is quite consistent with the fiscal year 2004 approved budget profile——
Mr. GORDON. Okay. So what does that cost?
Dr. MARBURGER [continuing]. Up to about—the NASA budget in the year 2020, according to this, would be about, what is that, $22 billion.
Mr. GORDON. But what is that cumulative cost, then, to get to the Moon by 2020?
Dr. MARBURGER. The—I mean this includes the entire NASA budget and their components. It looks like only about——
Mr. GORDON. Well, again——
Dr. MARBURGER.—2/3 of that——
Mr. GORDON [continuing]. If I could, did the President never ask you what the cost of this program was going to be?
Dr. MARBURGER. The President understands that we are enabling all future space exploration by putting into place——
Mr. GORDON. Okay. Please, you know, please just—you know, we have a short amount of time.
Dr. MARBURGER. And the——

Mr. GORDON. Let me ask you—just if I could ask you this. Did the President ever ask you what this was going to cost? Yes or no, please, sir.

Dr. MARBURGER. Yes, of course.

Mr. GORDON. All right. And what did you tell him?

Dr. MARBURGER. And we showed him this chart.

Mr. GORDON. Okay. And—all right. And what does that—could you tell me? Could you add that up and tell me what that means then?

Dr. MARBURGER. The—I mean I can't—I would have to do some calculations on this chart. The——

Mr. GORDON. So you didn't—you haven't done calculations——

Dr. MARBURGER. It clearly——

Mr. GORDON [continuing]. Before?

Dr. MARBURGER. Yes, I am sorry. This—these precise numbers that you are asking me here are not part of what I carry in my head.

Mr. GORDON. I am—just a general number of what is it going to—you know, did the President ever ask you, "What is it going to cost to go to the Moon?"

Dr. MARBURGER. Actually, the question of going to the Moon is part of the program that would be accomplished according to the timetables——

Mr. GORDON. Okay. Well, get—please——

Dr. MARBURGER [continuing]. In this——

Mr. GORDON [continuing]. I am not trying to be argumentative.

Dr. MARBURGER. Well, they are right in there. They are——

Mr. GORDON. Okay.

Dr. MARBURGER. I am looking at the same pictures that you are.

Mr. GORDON. All right. So when the President asked you what it is going to cost, you didn't tell him? You just gave him this chart?

Dr. MARBURGER. No, there were tables of numbers associated with this that do appear in the fiscal year 2005——

Mr. GORDON. All right. Did the President ever——

Dr. MARBURGER [continuing]. Presidential——

Mr. GORDON [continuing]. Ask you what anything was going to cost?

Dr. MARBURGER. Yes, of course.

Mr. GORDON. Okay. What——

Dr. MARBURGER. Yes.

Mr. GORDON [continuing]. Did he ask you, and what did you tell him?

Dr. MARBURGER. I would like to respond to that in writing so that I can be sure of my response.

Mr. GORDON. Okay. So you——

Dr. MARBURGER. I would prefer not to try to calculate it from this graph.

Mr. GORDON. All right. So—but you don't have to calculate it, but if you were there in this environment rich—you don't remember him asking you what anything was going to cost and what you told him?

Dr. MARBURGER. No, I am sorry, Mr. Congressman, that I am unable to answer these questions that you are asking in precisely this form. The emphasis is—the emphasis in this vision is on——

Mr. GORDON. Okay. Well—and I have got to——

Dr. MARBURGER [continuing]. Affordable——

Mr. GORDON [continuing]. Go on. I will stop.

Dr. MARBURGER [continuing]. Sustainable, affordable——

Mr. GORDON. Okay. I got it. Stop.

Dr. MARBURGER [continuing]. Budget. And so we——

Mr. GORDON. You said you were going to——

Dr. MARBURGER [continuing]. Do not want to devote more of our discretionary budget than we can afford——

Mr. GORDON. Okay.

Dr. MARBURGER [continuing]. In any one year, and we will adjust the timetables——

Mr. GORDON. I understand. It all depends. All right. Again, you said you would respond to me. My question to you was did the President ever ask you what anything was going to cost?

Dr. MARBURGER. Yes.

Mr. GORDON. What were those various things, and what did you respond?

Dr. MARBURGER. And——

Mr. GORDON. Okay. And you don't have to do it now. That is fine.

Dr. MARBURGER [continuing]. I would be glad to respond.

Chairman BOEHLERT. Thank you, Dr. Marburger, and submit it for the record. I would observe that the 2005 budget projects out to 2009, not beyond. So those are the figures we have——

Dr. MARBURGER. The initial one in the budget, but this entire graph, up through 2020, is an important part of the vision. It shows how the funds available for exploration, for a credible exploration program, can be made available within an affordable envelope. This is a very important part. We—the reason we are having this problem is that we are looking at this from different perspectives. This is not an Apollo-like project. This is a—the key word is to enable future space exploration. We are going to become a space faring Nation to take advantage of the assets and the resources that exist——

Chairman BOEHLERT. Thank you, Dr. Marburger.

Dr. MARBURGER [continuing]. And the opportunities for discovery.

Chairman BOEHLERT. Thank you, Dr. Marburger. I just want you to know that it is evident, in that we have just had two of us who have had the opportunity to ask some questions, that we are very interested in getting as precise information as we possibly can get. And we understand fully, and some instances are going to have to be ranges. And we fully understand that there are assumptions, and we are assuming, and we want this verified, that you can give us the ranges and further assume that we are probably looking at the midpoint in the ranges. And some things go well and the costs are reduced. Other things don't go as well as anticipated, and costs are increased. So we are dealing with ranges, but we want as much specificity as we can possibly get. For example, we have been told by the NASA Comptroller that a development to full completion of the CEV could cost as much as $15 billion. True, Mr.——

Mr. O'KEEFE. Oh, absolutely. And that is a fair range, and to that very specific point, of what is the development of that capability, that unique asset. The answer is in that range of $15 billion. Everything we did on the orbital space plane, 75 percent of that effort is certainly transferable to the same kinds of activities we would pursue with crew exploration vehicle under Project Constellation. And that is in the range of about that. $6.5 billion of it is what is in the budget before you between fiscal year 2005 and 2009.

Chairman BOEHLERT. Um-hum.

Mr. O'KEEFE. And as we move through those spiral development phases, the definition of that particular estimate will become much better understood. The first spiral development product that you have to deploy that will be unmanned, certainly by the end of this decade, is a capability that is well within the range of the amounts that we have budgeted so far. And depending on what the outcome of that is as to whether you commit future resources to it. But the overall cost of that asset to go anywhere is in that range of cost.

By program, by mission objective, that is a different question. It depends on how you employ it, where you go, when you do it, how many times. Those are all factors that need to be resolved.

Chairman BOEHLERT. Thank you very much. I do appreciate that.

Mr. O'KEEFE. Thank you, Mr. Chairman.

Chairman BOEHLERT. With that, the Chair recognizes the distinguished Chairman of the Committee on Space and Astronautics—Aeronautics, Mr. Rohrabacher.

HEAVY LIFT

Mr. ROHRABACHER. As long as you don't say the extinguished Chairman, that is all right.

I am just trying to—and I think that the question Bart is asking, Mr. Gordon is asking, is a very relevant question, and I think that we do need specifics. And I believe—Mr. Gordon, I am complimenting you on your questions, Bart. Let me just note that I believe the question—line of questioning that you had is very justified, and we do need specifics.

But let me—if I could go through some of the general areas, and maybe you could come back to us with as much specifics as you can. In order to handle this first phase that we are talking about in terms of the President's vision, our first step toward the Moon, we have a CEV, which is a crew exploration vehicle, that we will have to develop. Will we be developing a heavy-lift capability, a new rocket that would have heavy-lift? Is that necessary as well?

Mr. O'KEEFE. No, sir, I don't think so, but it could evolve that way, but that would involve a back to the future approach, if you will, of saying, "Let us do this just like we did Apollo. Let us put everything on one asset."

Mr. ROHRABACHER. Okay.

Mr. O'KEEFE. "And just brute force it right off of this rock." Okay. That is the approach we used with Apollo. The approach we have defined here is a spiral development approach in which you develop each component and launch them separately, so as a consequence, the available assets that are in inventory today at the

initial phases of deployment, the expendable launch vehicles, Atlas and Titan, as well as the potential combination of a Shuttle stack——

Mr. ROHRABACHER. Um-hum.

Mr. O'KEEFE [continuing]. There are a number of different alternatives that you could pursue, when given the chance.

Mr. ROHRABACHER. When do we know—when do you think we will know if a new heavy-lift rocket is necessary to actually fulfill the requirements?

Mr. O'KEEFE. I think certain definition of that would be reasonable within this next six months to a year.

Mr. ROHRABACHER. Okay.

Mr. O'KEEFE. Because if it calls for something larger, in terms of mass——

Mr. ROHRABACHER. Right.

Mr. O'KEEFE [continuing]. Then you have got to go beyond the scope of Atlas and Titan or Shuttle stack or something else.

Mr. ROHRABACHER. But there may be ways of doing this, having a certain amount of support equipment being on another rocket that——

Mr. O'KEEFE. Exactly.

Mr. ROHRABACHER [continuing]. Doesn't need to go up with the other——

Mr. O'KEEFE. Exactly.

Mr. ROHRABACHER [continuing]. With the crew.

Mr. O'KEEFE. And at each component, you could potentially do a launch and assembly thereafter, as opposed to a one-size-fits-all, let us get the static displays of the Saturn Vs out and stand them straight up and try to use them again. I mean, that is just not—that is not part of the cards here.

ROBOTIC EXPLORATION

Mr. ROHRABACHER. Okay. The—and also another element of this is, of course, an expenditure that we are going to need to know the specifics on is how much it is going to cost for the robotics. Seeing that we don't—the President just outlined the vision. We don't know exactly what robotics capabilities will be necessary right now, but how long will it take before we know exactly what those capabilities——

Mr. O'KEEFE. Sure.

Mr. ROHRABACHER [continuing]. Will require and how much that will cost?

Mr. O'KEEFE. Yes, sir. With precision, I can give you the numbers, and we will submit it for the record here, on the future Mars exploration missions we have that are all robotic.

Mr. ROHRABACHER. Right.

Mr. O'KEEFE. And they are in—they are scheduled for 2007 and 2009. And there are some very specific missions that go with that that we can give you a price tag of what that out term—out year projection is. The lunar missions are, as Mr. Gordon was inquiring a little earlier, will require the development here over the next six months. But again, I am looking at something in the range of $500 to $600 million worth of initial lunar robotic exploration capacity that will be——

Mr. ROHRABACHER. Right. But what we——

Mr. O'KEEFE [continuing]. Laid out on the table as well.

Mr. ROHRABACHER. But we actually have not determined—I mean the President, you know, has just set down this goal. We have not determined exactly to what extent the robotics' cost development will be, because we don't know how much robotics capability we will need, at this point, in terms of the Moon——

Mr. O'KEEFE. Yes, sir.

Mr. ROHRABACHER [continuing]. Part of the goal.

Mr. O'KEEFE. That is correct.

Mr. ROHRABACHER. Because we may need robotic—robots that, for example, might do extensive work with soil analysis or——

Mr. O'KEEFE. Yes, sir.

Mr. ROHRABACHER [continuing]. Other type of exploration, and we may not, but that will be determined within the next six months.

Mr. O'KEEFE. Yes, sir. And as a reserve in the five year projection of the kind of resources that could—would be available for, specifically, those robotic objectives.

CEV COSTS

Mr. ROHRABACHER. Okay. So this—the crew exploration vehicle—let me note that I think that $15 billion for the development of a crew exploration vehicle is a pretty big ticket item, and that sounds a little out of line to me, and I am really going to look at that as it goes—moves forward.

Also, I would suggest—there are rumors running around that people might be thinking that they are going to design this crew exploration vehicle that is going to be used both on the Moon as well as on the Mars part of this Presidential challenge. Just an admonition from this Congressman, just as you—it is hard to plan budgets 20 years out, I think that the idea of trying to have a vehicle that we are planning right now that is going to be accomplishing both of those goals even though those goals will be about 10 years differential and when you achieve those goals is not really a rational way to plan that stepped approach that you are talking about.

Mr. O'KEEFE. Indeed. And that is the precise reason why answering the question of exactly how much it—will it cost to do the following thing is, right now, an imponderable point, because, depending on how you array the components necessary and develop them in each of the stages of the spiral development for the crew exploration vehicle, gives you a different configuration.

Mr. ROHRABACHER. Yes, sir.

Mr. O'KEEFE. And again, the answer on Project Constellation right now is finite of $6.5 billion in the budget right there by line item, 2005 through 2009, and then the additional costs thereafter to develop all of the following spirals for a human rating capacity is what would occur in the next phase——

Mr. ROHRABACHER. Well, we do expect—and as I say, Mr. Gordon is absolutely right in asking for specifics, but at—but I think that the question is more appropriate to say that we expect specifics as we move forward.

Mr. O'KEEFE. Yes, sir.

Mr. ROHRABACHER. And we don't expect to have just, you know, a general plan in the future.

Mr. O'KEEFE. Exactly. No, at each stage, you get a real—you know, greater definition.

Mr. ROHRABACHER. All right. Now let me note this. The Space Launch Initiative, which is something that I put a lot of time and effort in getting into the budget and finally I got it accepted the idea that we were going to actually have some part of the budget committed to developing new launch systems. That is the—seems to be the line item in the budget that has been most cannibalized by this effort. I am not upset about that. I would expect that. Let me just say that even though this has been my baby, I would expect that that—those funds would be used in a priority fashion to help fulfill the President's goal. So—and I would hope that all of the rest of us, as we move forward, we all have things that we pay special attention to in the budget and things we have pride in that we are—don't let our ego get in the way of letting that—those funds be used to help us prioritize and achieve the goals the President has outlined.

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

Mr. ROHRABACHER. Yes, sir.

Mr. O'KEEFE. And if I could, Congressman, very quickly, there is—the Space Launch Initiative did its job. You did exactly what I think it was intended to do, which is it served up the options and we made the selection of the options. It worked exactly right, and it is—it gave—it provided us the capacity to be where we are right now. So I thank you, sir.

Chairman BOEHLERT. Thank you very much.

And I think it is very evident from what has been said to date that all of us are looking at this, not in isolation, not as just one piece to the overall puzzle, we want to see the big picture and how this impacts on every other piece so that we can make rational judgments and develop responsible policy.

Speaking about responsible policy, Mr. Lampson?

Mr. LAMPSON. Thank you, Mr. Chairman.

THE END OF ISS

And speaking of what you were saying, I think you led right in to what I wanted to ask. I have a couple of questions. I always—there are many things that we want clarification on. Let me try to focus on two of them in my very short five minutes here.

Mr. O'Keefe, NASA's budget charts indicate that there won't be U.S. funding for the International Space Station beyond 2016. We need to know what you intend to do with the U.S. portion of the Space Station beyond that time. When you responded to Mr. Gordon's written question on that topic, you said then, "NASA will continue the operation and maintenance of the ISS consistent with the U.S. space exploration goals." However, that statement is contradicted by the budget plan that accompanies the President's initiative. So which is it? Is NASA going to continue to fund the U.S. participation in the Space Station after 2016? If so, about how much will it cost and for how long? And if not, what did you mean by Mr. Gordon's question and your response to Mr. Gordon's question?

And let me say one other thing before you answer that. Your response to Mr. Gordon also stated: "Any final decision about the U.S. Government's role in the ISS, once this research is complete, will not need to be made until the middle of the next decade." Are you seriously saying that the U.S. can wait until the middle of the next decade to let its international partners in the Space Station program know what the U.S. intends to do? That sounds pretty unbelievable to me, and I want to know if that is really what you are saying.

Mr. O'KEEFE. Yes, sir. I appreciate that, and thank you for the question.

First of all, the objective of the next dozen years between now, 2004, and 2016 is the targeted span that we are looking at to really refocus all of the research effort that the U.S. modules will be conducting, focused on human physiology and long-duration space flight consequence. So all of the other priorities that were outlined in the remap effort, you may recall a year and a half ago that we went through, of looking at what science prioritization, the answer now is there is one priority. We are focusing on life sciences. We are focusing on what the challenge is of understanding the research necessary to inform long-duration space flight.

Mr. LAMPSON. Is there an expectation, then——

Mr. O'KEEFE. Yes, sir.

Mr. LAMPSON [continuing]. That we can end that by 2016?

Mr. O'KEEFE. Yes, sir. That is the expectation is that that research will take us through the middle of the next decade of 10 to 12 years to achieve that. If it doesn't, we will have to continue that activity beyond that point.

Mr. LAMPSON. Okay. At what point do we have to notify our international partners of what we are going to do, because it impacts them as well?

Mr. O'KEEFE. Yes, sir, absolutely. And we discuss with our international partners on a regular basis. They are in—they are meeting and convening today. We will continue to do so on a regular basis, and we will constantly update them as we move through this. They do not feel as though there is an abandonment that is occurring here. Their view is that as we step through this, we have got to determine what the components and modules look like, what the laboratory segments look like, when they deploy, and how long we want to all deploy them—or operate them.

Mr. LAMPSON. In 2016, if this ends, is there a plan, then, to bring it back?

Mr. O'KEEFE. No, sir. Again, there is no presumption here that upon the completion of our research endeavor to examine the human physiology effects on long-duration space flight that we turn out the lights on Station. Our partners intend to continue operating——

Mr. LAMPSON. But we may give it——

Mr. O'KEEFE [continuing]. And we may, too.

Mr. LAMPSON. So our part——

Mr. O'KEEFE. And we may, too. So as a consequence, it is designed, through the next decade, to continue on. And there is no presumption here of turning off the lights on Station by the middle of the next decade.

Mr. LAMPSON. Okay. Are—okay. Well, let me go to my next one, because I am running out of time.

Mr. O'KEEFE. No, sir, the budget only goes through 2009. The budget only goes through 2009, so the longer-term projection is we are trying to give you visibility over what the research plan is. We are trying to lay out goals to the research community to say within the next 10 to 12 years, we have to conquer these particular challenges of long-duration space flight.

Mr. LAMPSON. Doesn't that end, on your chart, at 2017?

Mr. O'KEEFE. Yes, sir. That is the specific cost on—in the activities related to long-duration space flight, human physiology, life sciences research. How that may be adapted beyond that point to build a capacity on what Station could—can still afford is something that we have got an opportunity to examine.

Mr. LAMPSON. We have—we may have some more questions on that.

Mr. O'KEEFE. Yes, sir.

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Mr. LAMPSON. But right now, let me switch quickly to the issue of the Russian Soyuz. It is clear that we will have some dependence on the Russians for Soyuz crew transfers to and from the Space Station after 2010 when the Shuttle fleet is abandoned. It is also clear that we will need to acquire Soyuz vehicles for the Space Station starting in 2006, which is less than two years from now. We know that it takes about 18 months or so, 16 or 18 months to build a Soyuz. I wanted to make a comment about outsourcing our jobs and talent to Russia, but I won't. And in fact, in 2005, NASA's budget plan now includes a multi-year funding stream for ISS cargo and crew services that NASA concedes may include payments for Soyuz services. Yet, as we have discussed in the past, the Iran Nonproliferation Act prohibits such payments to Russia in the absence of a presidential certification on nonproliferation, and that has not been forthcoming.

And the State Department has made it clear in writing, in written testimony to this committee, that payments to U.S. companies purchasing Soyuz vehicles or services from Russian companies "would raise questions under Section 6 of the Iran Nonproliferation Act and would likely be viewed as an evasion of the law." Similarly, the State Department has made it clear to the Committee that having our other international partners purchase Soyuz vehicles or services from the Russians in exchange for compensation from the United States would also "raise legal questions under Section 6 and would likely be viewed by many as an evasion of the law."

So here we are. Your Administration is saying that you can't acquire Soyuz from the Russians without violating the INA, and yet your approach to the Space Station is critically dependent on a continuing supply of Soyuz vehicles. Do you plan to seek a legislative repeal or modification of the INA to permit you to acquire Soyuz? If so, when will you notify Congress of that intent? And if not, what specifically is your plan?

Chairman BOEHLERT. And that is a very important question. The gentleman's time has expired, but we are allowing additional time, because this is a—he has hit to the heart of a very important issue.

Mr. O'Keefe.

Mr. O'KEEFE. Yes, sir. Thank you, Mr. Chairman.

We are not seeking exemption to the law at this time. We are a—negotiating with all of our international partners on what our continuing challenges to operate Station will entail. Right now, the only means to achieve access to Station is by the Soyuz craft. There is clearly an intent on the part of all of our partners to expand the crew size aboard the International Space Station once Shuttle returns to flight and we continue to build out the capacity of International Space Station. So all of that will require a modification to our current agreements, which expire in 2006, among all of us as partners, all 16 nations. And we are enjoining in that question now, beginning today. All of the partners are in town, and there will be continuing activities through the end of March, early April with the heads of agencies to discuss exactly these points.

Our intent at this moment, at this time, is not to seek a—either an amendment to or repeal of the Iran Nonproliferation Act.

Mr. LAMPSON. Okay. And there is really not a plan yet. Thank you for your indulgence, but——

Chairman BOEHLERT. Yeah, you just said that. Your intent now is not to seek.

Mr. O'KEEFE. At this moment, on this date, no. We are beginning negotiations starting today with all of our partners on what the way ahead is for both cargo as well as crew transfer and building in the proposition of when we return to flight and how we continue to build the Station out and what all of those implications more—may portend. So we are beginning, among the 16 nations, to have that discussion, starting today.

Chairman BOEHLERT. I am sure, Administrator O'Keefe, you recognize as much as we do, the importance of this very issue?

Mr. O'KEEFE. Yes, sir.

Chairman BOEHLERT. Thank you very much.

Mr. ROHRABACHER. Mr. Chairman? Mr. Chairman?

Chairman BOEHLERT. Who seeks recognition? Mr. Rohrabacher.

Mr. ROHRABACHER. Just to point a personal privilege for one moment.

Chairman BOEHLERT. Yes, sir.

Mr. ROHRABACHER. Being in—being one of the co-authors of the Iran Nonproliferation Act and——

Chairman BOEHLERT. Mr. Rohrabacher, you are recognized for——

Mr. ROHRABACHER. For 10—for 15 seconds just to note that there are exceptions in that act, especially when the lives of American astronauts are at stake that could be, you know, analyzed in a way that are determined——

Chairman BOEHLERT. Interpreted.

Mr. ROHRABACHER [continuing]. Interpreted in a way that would not create the barriers that we are talking about. So it is possible that it is not the barrier that we think it is, but it has to be looked at very closely.

Chairman BOEHLERT. Thank you very much for that intervention.

Mr. Smith.

INTERNATIONAL PARTICIPATION IN THE ISS

Mr. SMITH. Thank you, Mr. Chairman.

Is it worth it—at this time of record-high deficit spending, is it worth it to borrow this money from our kids and our grandkids for this kind of venture at this time? As Chairman, the—as Chairman of the Research Subcommittee, and with the understanding that the main purpose of the Space Station is scientific research and as a place for the shuttles to travel to, I have often questioned witnesses on the justification for manned space flight as well as the Space Station. Some witnesses have expressed concern that the costs are too high and the benefits too few compared to the results that we could get by investing this money in other research that can better help us in our future, with research efforts as well as our economy. With $500 billion-plus deficits, limited dollars for research are there, and as we make this balance between our efforts, especially in manned space, versus unmanned space flight and the achievements that you demonstrated with the pictures with unmanned space flight. Part of the decision of this committee, and of the Appropriations Committee, has got to be the priorities on where we can best spend this money. It is going to—it seems to me that the question I have is with the growing reluctance of other countries to contribute. Is there a possibility that we should or we could put the Space Station expenditures on hold for the time being? Mr. O'Keefe, earlier you have stated before this committee that you thought it was possible to maintain the Space Station with unmanned flight. And I am just very concerned with borrowing with the tremendous pressure on the budget. And I would just suggest that we are going to reduce the budget below what the President has suggested overall. And so setting those priorities is even more important. And I am afraid that I am tempted with the comments that we have had from other countries of their reluctance to contribute more and more to the Space Station. With the cap that we set a few years ago of $25 billion, number one, should we consider delaying this project for the time being? And number two, are other countries more and more reluctant to contribute more and more dollars to their cooperative effort in the Space Station?

Mr. O'KEEFE. Well, thank you, Congressman, for that very important question.

If anything, what we have seen demonstrated in this past year is exactly the contrary. Our partners have stepped up in a way that is absolutely unbelievable. We have paid not one dime more for the continuing activities of access to the International Space Station during this time, which we have grounded the Shuttle, over this past year. So all of the activities, all of the logistics support, everything, has been contributed to by our partners and in participating in that, it has not cost us one dime more as a consequence of it.

So as a result, if anything, the depth and strength of this partnership has been demonstrated——

Mr. SMITH. Yeah, but you say not one dime more, but what—over the next five years, what we are looking at is about a $12.6 billion increase because of this new suggested venture.

Mr. O'KEEFE. Yes, sir. You have asked two different questions, so I will try to focus on the first part, which was your questions about International Space Station, and then we will get to the exploration discussion, if you would like.

But the first part is what we have done during the course of this time, and your assertion that reluctance of partners to contribute. No, to the contrary. They have been contributing more in this span of the last year than what, frankly, I would have ever anticipated and what we may have otherwise thought was possible. And the continuing operations of Station are occurring today as a consequence of the partnership and the strength thereof.

The second point would be that our whole focus now on the research on International Space Station, once we return to flight and we have continued building the—and complete the assembly of Station, is to focus on life sciences research, human physiology. One of the biggest problems we have to conquer is the degradation of muscle mass and bone mass. If from that we can also understand how to arrest the consequences of osteoporosis——

Mr. SMITH. Or radiation, but this is within——

Mr. O'KEEFE [continuing]. Or radiation——

Mr. SMITH. This is within the Van Allen Belts, so I have been told that the simulation can be done just as adequately on the ground in terms of the radiation consequences.

Do we want to send a man in space? Do we want to occupy Mars or the Moon at this time when the economic pressures are so great on this country? And is it something that we can put off, or is it something that we should consider abandoning altogether?

Chairman BOEHLERT. The gentleman's time has expired, but——

Mr. SMITH. I mean, we are cutting down on the budget——

Chairman BOEHLERT [continuing]. Dr. Marburger——

Mr. SMITH [continuing]. For NSF.

THE EXPLORATION VISION AND CURRENT BUDGET CONSTRAINTS

Chairman BOEHLERT [continuing]. I think, as the Science Advisor to the President, is in a good position to get a broader view on that question.

Dr. MARBURGER. We must not abandon the vision of space exploration. I believe that the vision of space exploration is an inspiring vision. There is a reason for humans to be in space. We must overcome the technical difficulties and obstacles in the way, and as we make the investments to do so, we will also energize our economy. There is no question that the technologies that are necessary to embark on this venture, on this new vision for space exploration, will have a very positive effect on the—on our economic competitiveness and on the basic technologies that form the infrastructure of our society.

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

Mr. SMITH. Thank you, Mr. Chairman.

Chairman BOEHLERT. Ms. Lofgren.

ARC ACCOUNTING AND FIELD CENTER CLOSURES AND "THE MILITARIZATION OF SPACE"

Ms. LOFGREN. Thank you, Mr. Chairman, and thank you, witnesses, for being here today.

I have a bunch of questions, and we don't have a lot of time, so I may follow up in writing with some of the questions that I have. But one of the things that I am puzzling over is your new accounting system and how to figure out, really, what is happening on the ground in the proposed budget. And taking a look at Ames Research Center, which I know that you value and you have visited on many occasions for the nanotechnology work that they are doing in robotics and the like, I see a $90 million reduction in the proposed budget, and it is in something call service pools. Now I think $55 million of that is the wind tunnel that is going away, but I am not clear how the other $35 million—is that a programmatic cut or exactly what is that? That is question number one.

I have another question, which relates to the analysis that is apparently going on by a guy that you have brought on from the Navy who used to do the base closings, and I understand that this Mr. Casey is going to do real property mission analysis for NASA. And I have a concern about that, because certainly we have land that are assets to the agency, but the land is really not the sum total of the asset. I mean, it is the human power. I mean, it is so much more than just taking a look at real estate and how the science will be integrated in the analysis. I am interested in hearing from you and obviously all of the Science Committee Members will want to be involved in this process, and I am wondering if it is your intention to close one or more centers, and if so, you know, what the time frame is and the parameters are and the like.

And finally, I have an interest and a concern over the future of space as a demilitarized zone. I—you know, in past years, in past Administrations, we have talked about space exploration, but I see the word security popping up in the discussion of space at this point in a way that is relatively new. And I am interested in whether the Administration has a design or an interest in arming space in a way that humankind has not done in the past.

So those are my three questions for now, and I will follow up with you in writing on the others, if I may, Administrator O'Keefe.

Mr. O'KEEFE. Yes, indeed, there is a transfer that has occurred between 2003 and 2004 and now continued in 2005 of now capturing all of the costs associated with an activity in what is called a full-cost——

Ms. LOFGREN. Right.

Mr. O'KEEFE [continuing]. Accounting method. So now when you look at a program, you see the total cost of what it takes to carry that out as opposed to fractions of it or incremental pieces that are buried in lots of other locations. You can now make an informed decision each year on what you think the value of the program is and what—one of the advantages of the discussion we had earlier here is we will be able to add, with precision, each year exactly what the cost of that next increment of achieving these next exploration goals we will encounter.

Let me give you a table, for the record, if you would, of the comparison year-to-year as it pertains to the Ames Research Center budget, but there is a specific effort that needs to go on in the next few months, it will probably be completed by summer, to really transfer all of the data to be comparable apples to oranges so you can see what the differences are. Because in the one case, you had to assemble it all based on all of the disparate pieces. Now you get the assemblage all in one place. And we will provide that for the record (see chart below), so I couldn't speak to the specific——

Ms. LOFGREN. All right.

National Aeronautics and Space Administration

Ames Research Center
FY 05 President's Budget

	PY 2003	CY 2004	BY 2005	BY + 1 2006	BY + 2 2007	BY + 3 2008	BY + 4 2009
21 Ames Research Center	$885.0	$727.5	$716.2	$702.8	$698.3	$661.3	$657.6
Personnel	$175.1	$120.2	$114.1	$116.4	$116.9	$116.3	$121.0
Travel	$4.6	$4.2	$4.3	$4.5	$4.8	$5.0	$5.2
Procurements	$704.8	$408.0	$386.3	$365.7	$357.7	$316.7	$303.4
Center G&A	$0.2	$128.8	$137.7	$138.0	$136.3	$139.1	$142.3
Service Pools	$0.3	$66.2	$73.8	$78.3	$82.7	$84.2	$85.7
Total	**$885.0**	**$727.5**	**$716.2**	**$702.8**	**$698.3**	**$661.3**	**$657.6**

Mr. O'KEEFE [continuing]. Differences between that dollar versus the other dollar at this moment.

Ms. LOFGREN. So the reduction from $172 million to $74 million is just little bits and pieces? It is not a particular program that is being——

Mr. O'KEEFE. Indeed.

Ms. LOFGREN [continuing]. Proposed?

Mr. O'KEEFE. Indeed. And again, I will give you more specificity on that.

Ms. LOFGREN. I would very much value that.

Mr. O'KEEFE. Yes, ma'am.

On the second point, the gentleman we have recruited in is a fellow named Cassidy——

Ms. LOFGREN. Right.

Mr. O'KEEFE [continuing]. And he has been—was—in the last Administration, was at the Defense Department during the base realignment effort——

Ms. LOFGREN. Right.

Mr. O'KEEFE [continuing]. In 1993 and 1995. He has been brought in a month ago, following a comprehensive effort that we conducted last year to look at real property assessments, what do we have out there, just in terms of inventorying what we have. The approach that we asked for and have developed now, developing a strategy is how do we use those facilities in the most cost-effective way? There is no specific intention to look at a realignment or closure activity. It is more just to inventory what we have. His expertise was primarily in the realignment phase, working with indi-

vidual communities to assure transition from one mission to another. And so given that expertise and his capacity in that regard, we have asked that rather than reinventing the wheel ourselves, we bring him in for his understanding of how that activity occurs as we move ahead from this point.

There will be several different steps in this: a strategy, a business plan, and ultimately a mission analysis effort that we will work with you to define exactly what each of those steps are as we proceed ahead.

And finally, on the national security objectives, there is no implied or specifically stated objective to expand this to a national security mission. That is not an intention here. It is a broader definition of security of the Nation, economic and otherwise. That is what we intend to proceed with this exploration agenda.

Ms. LOFGREN. If I may, just a quick follow up on getting back to the real estate analysis as well. One of the issues, as you know, Ames is co-located at a spot that used to be the Moffett Naval Air Station, and there are huge toxic issues that, unfortunately, the Navy never dealt with, and I—that has unfortunately been the case all across the country. So the local communities have—it is not in my District, but the local communities have pushed for a long time for clean up of the—that base, and I am hopeful that if we are doing an analysis, we can make sure that—I mean the massive clean up costs are, once again, raised to the attention of the Navy. Maybe we can get them to do something about that.

And thank you very much for——

Mr. O'KEEFE. Yes, ma'am. Now this is an interesting irony. Having served as Secretary of the Navy at the time the Moffett Air Field was part of the Naval establishment——

Ms. LOFGREN. Right.

Mr. O'KEEFE [continuing]. And then coming back to NASA and finding we now have it, it seems to be a deed that I carry with me wherever I go, but it is one that we are evaluating and trying to assess exactly what the environmental impact would be.

Ms. LOFGREN. Finally, I would like to, not at this point, because other Members have questions and time is running short, but I do have some concerns about how full-cost accounting is working. I certainly don't have an objection to understanding overhead and how it works and the like, but I do have a concern when you have, I think, Ames and I think this is—would be also true at Langley where you have a multiplicity of science projects that are not huge projects and yet essential to the mission in robotics or whatever allocating the overhead, there is no consistent, one project, to do it, and so we may have the unintended consequence of really starving science projects that are going to end up to be essential for the broader mission later. And I know that you don't want that and I don't want that, but I am interested in how we might avoid that consequence.

Mr. O'KEEFE. You know, that is a very, very important question, and again, it is really—you want to make sure that the process you develop in this particular case doesn't serve, you know, an unintended——

Ms. LOFGREN. Right.

Mr. O'KEEFE [continuing]. Consequence like that. I mean, what we have tried to put together here is in full concert in compliance with the Government Performance Results Act. How do you develop a full-cost visibility in what is involved, we have introduced that, and that is the primary focus and objective we are after here, and a budget and program integration effort so you can see, with total visibility, what that will entail.

Chairman BOEHLERT. Thank you very much, Mr. O'Keefe.

Mr. O'KEEFE. I am sorry.

Chairman BOEHLERT. You are putting—you are bringing several of your hats back in now: former Secretary of the Navy, the OMB. We are getting you on all sides.

The Chair now recognizes Dr. Bartlett.

THE VISION'S FOCUS ON SCIENCE

Mr. BARTLETT. Thank you very much.

Mr. O'Keefe, I was pleased that you mentioned an emphasis on human physiology. In a former life, I was a human physiologist. I was involved with the very earliest space exploration. I was at the School of Aviation Medicine at Pensacola, Florida in the first suborbital primary flight, the monkey you may remember that the Army lost their monkey, Abel, when they were taking the implanted electrodes out and they gave him a general anesthetic. I then went on to Johns Hopkins University Applied Physics Laboratory where I was involved—you mentioned Ames. I was involved with a—we built a satellite to launch an experiment for Dr. Tourgal Tiarotti where he had developed the technique for putting an electrode in a single fiber of the otolith, which is the only organ in the body that specifically directly responds to gravity, so I have had a long familiarity with the space program and appreciate the importance you place on human physiology.

You know, I think that perhaps the best justification for going back to the Moon and on to Mars has yet to be articulated. Let me explain. This is a challenge that we face that has been building for more than three decades. Three decades ago, I was at IBM—by the way, one of the major reasons for this challenge is the tyranny of the urgent. The urgent always takes precedence over the important, and so here we are because we always—we let that tyranny exist. Three decades ago, I was at IBM, and we were concerned that we, at IBM, and we, the United States, were going to lose our superiority in computers to Japan. That just about happened for one simple reason: every year, Japan was turning out more and at least as good, maybe better in some respects, scientists, mathematicians, and engineers, than we were, and we knew, at IBM, that if that continued, we were not, at IBM, going to remain—be able to remain the world's premier company in computers.

As a country, we now face that challenge. It has been going on and increasing for three decades now. For the short-term, it is a threat to our economic superiority. All you have to do is go to one of our major—any of our major universities and look who the students are in the technical areas. Fewer and fewer of them are from this country. I have a son, who—our tenth child, who just got his Ph.D. two years ago from Carnegie Mellon. He was so fervently courted by our national labs that he felt compelled to go there. And

the reason he was courted was that very few of those graduates were American citizens and you can't get a security clearance to a foreign national, so he now is at—out in Sandia labs in New Mexico.

For the short-term, this is a threat to our economic superiority. We will not continue to be the world's superior—supreme economic power unless we turn out more scientists, mathematicians, and engineers. And for the longer-term, it is a threat to our national security. We will not continue to be the world's premier military power unless we turn out adequate numbers of well-trained scientists, mathematicians, and engineers. Our country desperately needs something that captures the imagination of our people and inspires our young people to go into careers in science, math, and engineering. Right now, the best and brightest of our young people are increasingly going into destructive pursuits. We have more and more lawyers and more and more political scientists. Mr. Chairman, we need a few of each of those, but we have gone beyond that few of each that we need, and we now really need something that entices our young people to go into careers of science, math, and engineering.

Hopefully this program, rightly conducted, will do that. You know, this really has to do with our national survival, and we are making an investment here, sir, that is going to pay big, big dividends. This is not a cost. This is an investment. I don't think we can afford not to do it. And I hope that when you do it, you do it in such a fashion that you do capture the imagination of our people and inspire our young people.

Because I am a physiologist, a scientist, and because this is the Science Committee, let me ask a question. It is not clear to me the extent that this initiative will be driven by science. In some of the documents, it talks increasingly about exploration. I would hope that in capturing the imagination of our people and inspiring our young people that you really do focus on science, because our people have a lot of curiosity, and this brings, you know—this really—science brings us there very well, I think.

You put the plan together. Are you going to continue to focus on science? Is that going to be a high priority that drives what you do?

Mr. O'KEEFE. Absolutely, Congressman. Thank you very much for the question.

It is an exploration agenda informed by the science objectives. There is a science objective behind each of the exploration activities that we would be pursuing. As we see playing out right now on Mars, on both of the Mars rovers, the objectives are very clearly—this is a good characteristic example of the precursor missions we are envisioning is they have very specific science agendas and objectives that are to be informed, and it is an exploration opportunity in addition to that.

To your earlier part, the—and just anecdotally as—in terms of what the interest level is among folks who are accessing what we are into and what we are doing, the website statistics I offered earlier, what—based on everybody that has filled out the surveys here, roughly 20 percent of everyone who is coming to the NASA website, of the six billion hits, 20 percent of them are K through 12 stu-

dents. 15 percent are college and graduate students. I mean, the level of interest in the kind of activities we are involved with here is inspiring that next generation of explorers. We want to continue that. And it is unabated. This is not a spike that has occurred in interest and is dropping off. It is continuing.

Dr. MARBURGER. I would just like to add that exploration is part of science. And as clever and fascinating as the Mars rovers are, their capabilities are very, very limited. Now we can imagine much more sophisticated and extensive robotic networks, but eventually, the complexity, and especially the need to do things at a distance where there are tremendous communication lags because of the distance of the destinations from Earth, they ultimately need human oversight. And the more sophisticated and complex the exploration and science missions become, the greater need there will be for human presence, not just to go out and plant flags, but actually to do something that is important in reaping the assets and the resources of space.

Mr. BARTLETT. Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you very much.

Mr. Udall.

HUBBLE

Mr. UDALL. Thank you, Mr. Chairman. I, too, want to welcome the panel and thank you for your testimony.

I am going to take my time to focus on the Hubble. And I feel moved to make a series of statements. I hope I will give you a chance to reply, but hang tight here.

I share the concern of a lot of people across the country about the decision that was made in regards to the Hubble, and I wanted to share a couple of perspectives that have been presented to me, if I might.

Dr. Marburger, you mentioned adaptive optics in your earlier statement, and I found that interesting and important, but I have since found out from some folks at the Association of Universities of Research and Astronomy that adaptive optics will be important, but they won't be competitive with Hubble until 2015, and that is because adaptive optics require guide stars to fix the telescope. And with that sort of an approach, adaptive optics will allow us to see one percent of the whole sky. The Hubble gives us 100 percent across the spectrum of wavelengths. Adaptive optics only work in the infrared wavelength, and Hubble works both in the visible and infrared.

There are two instruments that have been built in my District. I should offer that disclaimer that this is important to the 2nd Congressional District, the costs and the wide field three. And if we were to deliver those instruments on Service Mission 4, we would further enhance Hubble's advantages over land-based capabilities. The COS adds ultraviolet wavelength capability and the wide field three improves infrared and visible wavelength capability. So I want to just put that into the record.

If I might, let me move on and talk a little bit about the arguments that I think have been made to cancel the Hubble. The one has been cost, and I think if you really step back and look at the cost, I don't think that that argument really can be justified. An

extra mission is about $100 million. If we were to cancel the entire Shuttle program, and I think that is a legitimate reason on a cost basis, but to do a fifth mission, say, in a year to service the Hubble, from what I understand, it is in the order of $100 million, and it is a small cost relative to the cost it takes to maintain the army of engineers and technicians.

The second argument is the safety argument. And I share your concerns about safety, but I think you can make the argument—I don't really think, I believe you can make the argument, if it is safe enough to fly to the ISS, then it is safe enough to fly to Hubble. So we have asked, as Congress, manufacturers to make $167 million worth of instruments that I mentioned, the wide field and the COS, only to be told that we are not going to fly those instruments to the Hubble because of safety concerns. But if that is the behavior we are going to accept, if we are going to work off that approach, then what guarantee do we have that if we spend billions to prepare a manned Moon or Mars mission that in the future we are not going to get cold feet and cancel that mission?

So in sum, it is difficult for me to understand, if we are too risk-adverse to send up a servicing mission to Hubble, where does that leave us if we are—when we are talking about going to a piloted mission to Mars or the Moon? When I look at the CAIB's recommendations, and I am going to quote their recommendation with regard to safety in on-orbit repair and inspection capability for the Shuttle. I want to quote: "The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking."

Now this is an unambiguous recommendation that applies to all flights, whether it is the Space Shuttle or for some other mission—I mean to the Space Station, excuse me. The initiative of the President calls for retiring the Shuttle in 2010, which means there would be another 25 to 30 flights. When does NASA intend to comply with the recommendation that I just read? In the first three flights? The first five? The first ten? Because at that point, if you are flying—if you are complying in the first 10 flights, even the first 15 flights, that still provides a window to do that servicing mission to Hubble and keep it up and running for another seven to ten years before the Webb is fully operational? I guess I have left you a little bit of time to answer my question.

Dr. MARBURGER. Good. Let me respond briefly to the science issue. No one is disputing that the Hubble is a very valuable instrument. It is an extremely useful and productive instrument, and the—I am not suggesting that adaptive optics is a killer argument here. But it is also true that the Hubble's uniqueness is diminishing and that it has, essentially, approached the end of its design life. Yes, we could continue to keep it alive by servicing it in this way, but there are alternative ways of getting the same or similar scientific data so that the risk-benefit equation has been altered as a result of technical progress. It is—that is a point that hasn't been made very strongly in this discussion. And I just thought it was important to make it. I am not suggesting that the decision is easy or that there aren't still some unique qualities that the Hubble has.

But I think the deliberations of the National Research Council group on the decadal surveyor are quite interesting in its context, which is why I quoted them.

As far as risk is concerned, risk is also, to some extent, a technical issue. And I believe that the CAIB and Admiral Gehman are among the experts on the issue of risk, and I do think that it was a very wise decision by the Administrator to call upon them to assess this aspect of the Hubble equation.

SHUTTLE RTF

Mr. UDALL. If I might, I would ask the Administrator, yeah, his thoughts on when we would have that capability to repair the Shuttle, the autonomous capability. And then if I could, since the Chairman has been indulging all of us, if you would give us a sense of where are we with the review, Admiral Gehman's role, and how do you intend to respond to his recommendation or his comments?

Mr. O'KEEFE. Yes, sir——

Mr. UDALL. And Administrator O'Keefe, if I might just interrupt. Dr. Marburger, I just was passed a note. Somebody reminded me that the B–52 also had long past design life, but it is still useful, so I think that is important to acknowledge that there are technologies that have long-time applications for us.

Mr. O'KEEFE. This was among the most painful decisions I have ever had to confront. It is a remarkable piece of scientific achievement and its capacity to continue to operate is just amazing. That said, my concern was not generated by a risk-aversion, Congressman; it was more generated by a capacity to honestly tell you that we intend to embrace the recommendations of the *Columbia* Accident Investigation Board report, and that facing the prospect that the point in which that mission, singularly the only mission that would go to other—any other location than Station, would not be able to achieve, I believe, at the time of that launch, compliance with all of those recommendations in the manner in which we said we would.

The issues you identified are among many that are involved in this particular question. The autonomous repair capacity has to be demonstrated on the first two flights. That is our objective. That is our approach in what we want to do. I have no idea whether that is going to be successful or not. So here we are making a decision about its success before we have ever demonstrated it. That is point one.

The second one is it requires the development of tools and capabilities we currently do not have in the inventory and would have to develop in order to do this, and yes, that is right, we would have to use it for Station as well as Hubble. But nonetheless, they have not been developed at this time, and won't be demonstrated until those first two flights. And so as a consequence, we would be assuming success at a time we are planning on a servicing mission when we could be diverting that attention toward how to maintain and operate this capacity for a longer period of time than we are currently expecting. There are a number of different ways we could do that, short of a servicing mission. So those are the kinds of things we are trying to examine as well.

The third factor that comes to play is the question of contingency planning, of what do you do in the event of a challenge, a problem, much like we saw on the *Columbia* mission. To the extent that were to occur, the objective on Station is you have multiple means to examine the Shuttle as it approaches the International Space Station on a number of maneuvers we have designed. And then in turn, as it docks, you have the capacity to examine it thoroughly. There is no comparable means on Hubble. So as a result, the only way that you can accommodate this is to literally stack two Shuttles, two orbiters on two pads, the second one being available in the event of a contingency, and the only means by which you can achieve a safe haven maneuver for the damaged Shuttle would be to literally tether the entire crew across during a mid-orbit maneuver where you bring everybody outside and you put what would amount to about 10 people on one Shuttle flight to bring them home. We have never tried it, we have never performed it, it is strictly on paper, and a full analysis of that was contained in the *Columbia* Accident Investigation Board's recommendations in the appendix.

THE ROLE OF CEV

Mr. EHLERS. [Presiding.] The gentleman's time has expired. I thank you for the explanation.

I happen to be next on the list.

Unfortunately, I have approximately two hours worth of questions. I thought, perhaps, I could arrange a private briefing, but now that I have the Chair, perhaps I can just do it all here. But to—let me reassure my colleagues I will not do that.

Several observations, since time is limited, and then a few specific questions on the crew exploration vehicle.

I may sound like a naysayer, but I don't intend to be. I am supportive of the President's proposal. At the same time, I am very skeptical about many of the details of it. I am concerned about the assumptions that I see underlying that chart up there. Time doesn't allow me to go into the details, but with a history of cost overruns on major projects at NASA, I think I have good reason to be concerned. And that is not meant to be a derogatory statement. I know, as a scientist, you don't know what problems you are going to encounter until you get into when you do something brand new. But I am concerned about the impact on other science, both within NASA and outside of NASA. The effects on continuing our efforts on space science, I think we have to continue that unabated. Our Earth science that NASA does is incredibly valuable to our nation and to, in fact, our planet, and we must continue that.

I am concerned about the Mars mission, the purpose, the cost, the scientific value. I believe it must be an international effort. We simply can not afford that as a nation alone. I think, personally, it would be a foolish waste of money for us to go to Mars, given our present state of technology. We simply—we have to have better energy sources. We have to have better propulsion systems to even think about going to Mars.

Dr. Marburger, you mentioned the limited nature of the robots, and that is very true, and we all recognize that. At the same time, we can send approximately 1,000 robots to Mars for the cost of

sending one human and bringing that human back. And so we have to compare what we can do with 1,000 robotic flights compared to one human flight.

The—I am concerned about the Space Station, its cost, its value, the science that is going to be done. If that is simply going to be to determine the long-duration effects of flight in space flight, that is a mighty expensive way to do it, and that is something else I would like to explore with you at some time.

Let me down get down to a specific question on the crew exploration vehicle. And I am, first of all, very concerned, Mr. O'Keefe, with the idea that this is going to be the vehicle for the Space Station, for the Moon, and for Mars. And I need clarification in that. What are you envisioning this vehicle to do? Is it—I mean, that seems to me too much to expect from a single vehicle. Isn't that likely to lead to the same problems we have with the Space Shuttle, that we expected too much of it, and it ended up being very, very expensive? I would hope that you would not even think about developing a Mars vehicle until we are much further down the pike.

The—well, let me have you answer that, first, before we get into other questions on it.

Mr. O'KEEFE. Yes, thank you, sir.

The approach is not to devise or to develop a one-size-fits-all answer to this. No question. Instead, the spiral development approach that we are trying to lay out is to test each component individually, and then you size and derive variance, depending on mission requirements. You need a substantially less volume requirement to get from here to the International Space Station. You certainly need more volume in order to get to the Moon. You need even more to get beyond that. So at each successive stage, you are looking at a different assemblage of modules and components in order to achieve that task, but at its core are a handful of fundamental aspects that you want to develop. And that is what the spiral development approach is designed to do.

The initial approach in these next few years is—certainly by the end of the decade, is to demonstrate those spiral developments and launch, unmanned, those capacities to see how each of those components then, in turn, can be lashed together. But it is not an intent to have a one-size-fits-all approach. We are not going that direction.

Mr. EHLERS. Are you envisioning this to be a reusable vehicle, or are you leaving that as an open question?

Mr. O'KEEFE. Yeah, I don't know yet. I—there is a spirited argument on this one way—on both sides. But I—there is certainly no predisposition either way at this juncture.

Mr. EHLERS. These first specs that you are developing in four months, is that related to the Mars mission at all or is that strictly development of the crew of a CEV?

Mr. O'KEEFE. Yes, sir, strictly to the Project Constellation crew exploration vehicle to develop the initial requirements to go beyond low-Earth orbit, and that will be a very short list of things here what we have to build into that as a requirement set.

Mr. EHLERS. And when you talk about assembling components in space, are you talking about actual assemblage or simply docking and proceeding on from there?

Mr. O'KEEFE. Yes and yes. You could be looking at both combinations, it depends. I mean, what we have learned from the International Space Station is we can do this. It is an astonishing engineering effort to pull together components in the manner that we have. So it demonstrates that yes, this can be achieved, and it all is within the realm of doing it with a launch capacity that does not need to exceed what we presently have at—in the current inventory.

Mr. EHLERS. But it is also very expensive to assemble in space.

Mr. O'KEEFE. Yes and no. I mean, it is—once there, the cost to actually do so is an awful lot easier than trying to assemble it in space from scratch. If you have got components that are launched, as we are doing on Station, you literally are doing it with a very minimal set of requirements. The actual cost to get there, yes, is expensive, but that is mostly ground costs.

Mr. EHLERS. Well, do you envision also using these vehicles to carry fuel up there for additional missions to Mars or to the—even to the Moon?

Mr. O'KEEFE. It really—it depends on what we find. On the Moon, if there is a capacity, as I think Dr. Marburger has opined, of developing a means for renewable energy sources, that may be an option. Another approach from Project Prometheus, to the extent we are able to develop the propulsion and power generation capacities that we are anticipating to demonstrate on the deeper space exploration missions to Jupiter, there may be a capacity and a means to use that kind of capability for power generation on surfaces. So there are a number of options that could be explored in every one of these avenues, the answer of which will be found as we succeed at each of those steps.

HUBBLE AND RISK

Mr. EHLERS. All right. Let me comment on the Hubble for just a moment, too. I share the concerns expressed by Mr. Udall, and I am really surprised at the safety concerns. We have Shuttles that are flown 100 missions, and I assume you will take care of the problem that brought down the *Columbia.* I am not sure I agree with the need to visually inspect every Shuttle, or any space vehicle. You are going to have the same problem on the CEV. You can not visually expect—inspect every vehicle that you send into space. And this is a hazardous enterprise. The astronauts are test pilots. They have risked their lives before to test vehicles. We can't encumber a program with such absolute requirements for safety that we literally price ourselves out of doing it. And I don't expect you to respond to that, unless you wish, but I think we have to use a little common sense here and say we can't make these as safe as our family car.

Mr. O'KEEFE. Yeah.

Mr. EHLERS. In fact, they really exceed the safety of the family car. And let us recognize, there is risk to space exploration.

Mr. O'KEEFE. Um-hum. Well, thank you, Congressman. I couldn't agree more. It is—we are doing our level best to reduce the risk

to the level of what is humanly possible. That said, you are exactly right: there will always be an inherent risk in this operation, particularly with Shuttle. I think what the *Columbia* Accident Investigation Board demonstrated is there is a lot more inherent risk in this asset than what we had thought. And so as a consequence—and it is the things you don't know that are lurking out there as well that really worry you.

And in the case of the servicing mission, though, it is the common mission of each and every one of the variables. And when you add them up, it is a higher risk than the risk involved in going to Station. And so as a consequence, when you evaluate it on that basis, it is a higher margin of risk, and so therefore, it becomes—it turns on the question of is that acceptable. And my greatest concern, again, was finding ourselves in the position of having a Shuttle ready to go and not being in compliance with the *Columbia* Accident Investigation Board's recommendations as thoroughly as we need to, and in turn, then, making the choice about whether to launch the mission prematurely or watch the Hubble dissipate at that point.

So it really became a case of now is the time to make that kind of a call up front in order to make sure we redirect our energies toward getting the longest service life we can out of Hubble.

Mr. EHLERS. My time has expired. I don't totally agree with you on that, but we can discuss that later.

Mr. O'KEEFE. Thank you, sir.

Mr. EHLERS. Next we have—Mr. Feeney is next.

NASA'S BUDGET AND NATIONAL SECURITY

Mr. FEENEY. Thank you, Mr. Chairman, and thank you, Dr. Marburger and Administrator O'Keefe. I really appreciate you being here today. And you know, with space at this critical juncture in American policy, we really only have one of two choices, in my view, and that is that America can continue to lead space exploration in the future or we can remain in the status quo and we can atrophy and we can let somebody else fill the potential void. And for 30 years or so, as the Gehman Commission reported, NASA, in many ways, has been an agency adrift, largely because of a lack of a focused vision. And what we have needed is a President and an Administration that has provided a responsible but bold vision. And that is exactly what the President has now down.

We can pick it apart with 535 different views of what the optimal role of America ought to be in space, but if that is the way Congress is going to behave, then everybody will know who dropped the ball. I do believe that this vision, while I might have designed it slightly different myself, is focused. I think it is bold. It is affordable, $200 million a year, based on the way we spend money around here, is a relatively inexpensive, first-stage start. Much of the costs come out of programs that will become unnecessary, superfluous, or obsolete, and I congratulate you, because this is a lot more affordable. I heard figures like, not $1 billion, but $1 trillion floating around as—leading up to the President's announcement. It is an incremental approach. It is flexible. We can change as we get better with respect to the technologies we are developing. I want to congratulate you heartily.

I do want to suggest that there is a lot of talk about how we can best spend an additional billion dollars or so in the next five years on research. And it does become difficult, for example, to argue that finding a cure for Alzheimer's or finding a cure for cancer isn't just as important as exploring outer space. And that is a difficult argument to make. We have got a great record in our manned and unmanned NASA division in terms of providing some wonderful technologies that often are not well explained to the American people, but it has been—it has returned our investment, I think, many times over and will continue to do so.

But I want to focus on part of this potential that has not been talked a lot about today. One of the Congresswomen earlier expressed her concerns that security was suddenly being talked about as part of the President's vision. In fact, she is correct that a renewed spirit of discovery, the President's vision for U.S. space exploration that was just released in January, this is the President's proposal. It talks about the fundamental goal of this vision is to advance U.S. scientific security and economic interests. And I will tell you, I think it is important that America has to maintain and help maintain, with other peace-loving nations, the integrity of commercial travel, of exploration, both manned and unmanned, and I also think that we need to absolutely be prepared to help develop the technologies that will protect our space capabilities, which are absolutely integral to everything that our military does. Probably 99 percent of their sophisticated weaponry, planes, ships could not deport without their total reliance on the GPS and the other satellite capabilities.

And we are not necessarily talking about arming space through NASA. We know that is not your vision. What we are talking about is the absolute unknowable advancements that you can make through your technologies. The Wright Brothers weren't thinking about making sure that the United States Air Force had air superiority in the last 50 years as we won, not only World War II, but also the Cold War, in large part because of that capability. I am sure Mr. Ford, as he developed his assembly line, was not thinking about also having the best tank armaments and armored personnel carriers, for example. But the types of technologies that we are able to develop here, Dr. Marburger and Mr. O'Keefe, are absolutely essential for a lot of reasons, not the least of which is security. I am glad we have had this open discussion, because I will tell you this, if some other hostile nation is able to develop dominance in space technology, the consequences for American security are unimaginably horrible.

And I invite you to comment or not, as you like.

Dr. MARBURGER. Well, as Administrator O'Keefe said that national security was not a driver for this mission, but there is no question that the kinds of technologies whose development would be accelerated under this program would have security—national security relevance. And I can do no more than to agree that this—that there certainly would be consequences that would make us a stronger nation.

Mr. O'KEEFE. Well, I fully agree. There is no question. The spinoffs that occur here, and again, your analogies are exactly right, I want to associate myself precisely with your commentary, are the

kinds of things that we can develop through this technology advance and in turn can have applications there.

Chairman BOEHLERT. Thank you very much. The gentleman's time has expired.

Mr. Bonner.

Mr. BONNER. Thank you, Mr. Chairman.

Mr. O'Keefe, I represent the State of Alabama in the 1st Congressional District, and although Huntsville is not in my District, it is an important part of NASA's history and certainly an important part of the state's contribution toward the space program. Could you, since some of my colleagues have already raised the question about the President's proposal to—for the orbital space plane to be replaced with the crew exploration vehicle, could you tell me what some of the efforts of Marshall might be with regard to developing the orbital space plane that would be channeled into this new crew exploration vehicle program?

EFFORTS AT MARSHALL

Mr. O'KEEFE. Yes, sir. The effort that Marshall Space Flight Center and, indeed many of the contributors throughout the NASA community involved in the orbital space plane, is the foundation which we are building on with crew exploration vehicle. The efforts we undertook last year were absolutely imperative to understanding the scope of the task that we are about to undertake, which is looking at a beyond low-Earth orbit capacity. It is 75 percent common with an awful lot of the work we have already done. So much of that is resident there. And I can—I fully expect that our exploration systems enterprise, led by Craig Sterdle, will be examination all of those alternatives and bringing to bear the best of that talent that is resident within—at—certainly at Marshall for the purposes of expanding that particular effort and going forward within the next few months.

INA AND SOYUZ PURCHASES

Mr. BONNER. Let me shift gears now. If the Russian agreement to provide the Soyuz crew support ends in 2006 and it takes one or one and a half years to build a Soyuz module on the Russian production line, don't the Russians need the money flowing to them soon? And when will we know who is going to pay for these Soyuz flights starting in 2006?

Mr. O'KEEFE. Thank you, sir. Again, as I mentioned with Mr. Lampson and his commentary on this point, we are beginning negotiations and discussions with our 16—our 15 other partners in the International Space Station partnership today. And they are here in Washington. And in the weeks ahead, as we lead up to a head of agency meeting here at the end of March, beginning of April, likely in Montreal, the discussions will be over exactly this kind of question. How do we go forward beyond 2006 for the continued transfer and return vehicle capacity that our Russian partners provide? We are also intending on returning the Shuttle to flight and completing the Station activities. So as a consequence, all of those contributions will be discussed. And how do we expand expedition crew size, how many more vehicles will be needed.

The Europeans are bringing to bear the ATV logistics capability here in the next several months. It is going to be substantially greater than the Progress vehicles that we are currently using, so there are any number of variables that will go into those negotiations, so I expect in the next couple of months we will have clearer answers on the more specific definition of the questions you have asked.

Mr. BONNER. As a follow up to that question, if I might, why haven't we, at this juncture, had a crew vehicle for the Space Shuttle?

Mr. O'KEEFE. A crew vehicle for the Space Shuttle? I am sorry. I don't understand the——

Mr. BONNER. A—to model after the Soyuz, the Russian vehicle.

Mr. O'KEEFE. Oh, I see. Again, the Space Shuttle is, and was, designed to be not only a crew but also a cargo-carrying asset. The Soyuz is of no similar or comparable capability. It is strictly a crew complement. The recommendations of the *Columbia* Accident Investigation Board are that we design a capability that separates the crew from the cargo. So until this—until the time of the, I think, *Columbia* Accident Investigation Board's recommendations, we had looked to maintain Shuttle in a singular capacity only in low-Earth orbit in this mode. So now to look at evolving that out into a crew separated from cargo approach, as the *Columbia* Accident Investigation Board recommended, is where we are proceeding. Why we haven't done it before, I could only offer speculation. Why we are doing it in the future, I could tell you definitively, it is because of our recommendations and the President's direction.

Mr. BONNER. Let me shift gears one more time, please, sir.

Mr. O'KEEFE. Yes, sir.

CENTENNIAL CHALLENGES

Mr. BONNER. Could you elaborate on the centennial challenge prizes that NASA wants to start for space entrepreneurs?

Mr. O'KEEFE. This is an opportunity, and really very much in concert with the President's direction, of looking at new, creative ways to accomplish these tasks and, in turn, encourage the entrepreneurial approaches that are out there and let us figure out how we achieve those kinds of objectives by creating spirited competitions for their continued development. So we are intent on pursuing that direction.

Mr. BONNER. Just one final comment, not a question. All of us who remember growing up watching the Apollo space program takeoff and man land on the Moon taking the first steps and then we watched with pride in the Shuttle program and the tragedy of *Challenger* and *Columbia,* I think all of us, especially in this room and on this committee and really, as evidenced by the tremendous crowd that is here today on a day when the House is not in session, we support what you are doing. We are proud of the work you are doing. With that said, I think the American people, as we face these tough budget decisions, deserve a renewal of explanation of what space exploration has meant to them in terms of their daily lives, in terms of the advancements of medicine, miracles of medicine, and some of the other technological breakthroughs that have a direct link so that when we go home to our Districts, when we

go home and visit with the people that sent us here, we can give them an updated answer to the questions of why now, why this much money, why this bold a vision. And I would certainly encourage NASA to help us sell the story of NASA, and I think you will find willing partners here.

Thank you so much, Mr. Chairman, for giving me an opportunity to question——

Chairman BOEHLERT. Thank you, Mr. Bonner.

Mr. O'KEEFE. Mr. Chairman, if I could, very quickly, 10 seconds. I will get you a piece of paper that will give you the specific derivatives of all of the things we have developed over the course of the last few years that can be available for——

Chairman BOEHLERT. Mr. O'Keefe, I wish we had six billion hits on that. And let me suggest to you that it is critically important, in that part of your communications program, that you explain to the American people all of the benefits that have come from our investments in the space program.

Mr. BONNER. Mr. Chairman?

Chairman BOEHLERT. Yes, sir.

Mr. BONNER. Especially those investments made in Alabama would be very helpful.

Chairman BOEHLERT. Understandable.

The Chair recognizes Mr. Gordon.

THE COST OF THE VISION

Mr. GORDON. Thank you.

At the risk of being a broken record, I want to go back to the issue of cost, and I do so because I think I would be negligent in my job if I didn't. Now I don't want to overstate, but I think it is fair to say that most everyone, if not everyone on this committee, is, at a minimum, disappointed, potentially disillusioned, with the cost estimates that we have been given up until recently even on the Space Station and the benefits that we were going to achieve. So we need to go out in front of this.

And so, Mr. O'Keefe, you know, I had written you and asked you for some cost estimates. And in your response, if I—as I stated earlier, you said it depends on timing, scope, technology, and research. Here is what I would like to do and what I really think is important for us. Let us set up just a benchmark and then we can—knowing that we can move beyond that. And I will help—you can—you know, I want you to set up that benchmark. So we are going to say, okay, the first thing you said, you can't—we can't give a cost unless we know the timing. It could be from 2015 to 2020. Well, around here, things usually take longer rather than sooner, so let us say we will give you the time. We will fill in the blank: 2020. Then you say the scope, the specific—and that specific demonstration is carried out on the Moon as well as the number, duration, type, size of missions to support these demonstrations. Why don't you just take what you think would be the reasonable scope? Then the technology, the same thing, and the research. Just—let us set a definitive benchmark of—within these four areas, of what you think would be reasonable things to achieve. And then, can you cost that out for us?

Mr. O'KEEFE. For what objective?

Mr. GORDON. So that we know what we are getting into and so that—we don't want to get into a situation where later on we decide we can't afford this and we wish we hadn't spent all of this money because there might have been a better approach.

Mr. O'KEEFE. Yes, sir.

Mr. GORDON. That is the reason. And I think if—when you were at OMB, and if someone came before you, surely to goodness, you would have asked those questions.

Mr. O'KEEFE. This is the functional equivalent of making assumptions on what, 16 years from now, the cost of my mortgage payment will be, what the light bill will be, any number of different——

Mr. GORDON. Well, isn't that what you did with that chart up there?

Mr. O'KEEFE. No, what this projects here, sir, is the—between 2005 and 2009 is the specific amounts that the President has proposed in the budget.

Mr. GORDON. Oh, okay. So we don't know what we are going to get for it, but that is just what the proposal——

Mr. O'KEEFE. Yes, sir, we do. I am sorry. I apologize for interrupting you. Let me let you finish.

Mr. GORDON. Okay. Well, anyway, let us just—you know, again, surely, you know, I don't know what the interest rates are going to be in 10 years, but there are those folks that can make an estimate, and that is all I am asking you to do is to take the best information that you have and it can be prefaced by those estimates as to what you think those costs will be. I don't really think that is too much to ask.

Mr. O'KEEFE. Yes, sir, I appreciate that.

In the period of time of 2005 to 2009, as the budget is presented before you to——

Mr. GORDON. Yeah.

Mr. O'KEEFE [continuing]. From the President to the Congress, the total amount is $86 billion. That is the total amount we are requesting, proposing, projecting, forecasting to be spent on NASA activities. In this coming year, it is 16.2. That is the part that you have the most amount of control, in terms of redirection to, as well as those out-year forecasts.

Mr. GORDON. I just want to—I want to get your best—your—you know, once you plug in the blanks as the timing, scope, technology, and research what you think it is going to cost to do that particular job.

Mr. O'KEEFE. Yes, sir.

Mr. GORDON. And again, let me ask you, did the President ever ask you, at any time in these information-rich hearings, what the cost would be to go to the Moon?

Mr. O'KEEFE. What he asked specifically is what do we plan to spend in this five year span of time and does it create a balloon note. What this chart creates—or——

Mr. GORDON. But he never asked you what it is going to cost?

Mr. O'KEEFE. Yes, sir, he did, and I am trying to answer that. I apologize, sir.

Mr. GORDON. Okay.

Mr. O'KEEFE. $86 billion is the amount that we specifically identified in the span of time from 2005 to 2009. And what this chart attempts to demonstrate is in the out-years beyond that, not within the scope of the President's budget proposal to you, were we creating a set of commitments that would be larger than the annual rate of inflation increase that would be reasonably anticipated for a budget proposal. And the answer is no. The amount that is included here is a rearrangement, specifically, of the assets necessary to continue to pursue this exploration agenda informed by the scientific objectives, and as a result, what you see is a wind-down of the Shuttle program, a wind-down, ultimately, of the——

Mr. GORDON. So if we add up that top—I am color-blind, but I guess it is blue, that—you know, that blue chart on your chart. If we were to add that up, you are saying that would be the cost of getting us to the Moon, in your opinion?

Mr. O'KEEFE. I think it is the combination of robotic missions, manned human space flight missions, a whole range of things to go to Mars, the Moon, any other destination you like.

Mr. GORDON. Okay. So then you could tell us, then, you—and I will ask you then, if you would add up those amounts and tell us what you expect that we are going to get from that by the year 2020.

Mr. O'KEEFE. 2020.

Mr. GORDON. Yes, sir.

Mr. O'KEEFE. Yes, sir. Let me provide that for the record. It gives you a specific breakdown of what those little sliced segments mean. I can't—I have forgotten off the top of my head exactly what those individual pieces are, but I will provide that for the record, because that is a projection of what this might entail, beyond 2009, to demonstrate that we are not trying to pass on——

Mr. GORDON. Right.

Mr. O'KEEFE [continuing]. Additional costs beyond the scope and visibility of what Congress has before you right now.

RTF COSTS

Chairman BOEHLERT. Thank you very much, Mr. Gordon. Thank you, Administrator O'Keefe. We look forward to that written submission, because it is information we all wish to become more familiar with.

In dealing with cost, let me go on to something that is in the 2005 to 2009 time frame. NASA continues to refine its cost estimates to implement the *Columbia* Accident Investigation Board recommendations for Shuttle return to flight. We appreciate your efforts in keeping the Committee informed of the actions NASA is taking and the costs associated with the return to flight program. In November of last year, NASA estimated cost for return to flight at $456 million over the next five years. Two weeks ago, we received from NASA a letter with another cost estimate of more than $1 billion. The estimates have doubled in three months. We understand that this is a work—as work progresses, you are refining your estimates, and there is a lot of work left to complete. My question is do you expect cost to continue to grow, or do you think you have a pretty solid estimate right now? What areas of the return

to flight activity entail the greatest risk for increased cost? What areas entail the greatest risk of slipping the schedule?

Mr. O'KEEFE. To my knowledge, sir, the last update that we released about a week ago for return to flight and the continuing implementation plan, so in other words monthly we update that, still hovers in that neighborhood of about $450 to $500 million, is my recollection. If another piece of paper was sent to you, I am not familiar with exactly what the differences of those numbers are at this juncture. But——

Chairman BOEHLERT. Well, I have the document here. Let me tell you where the document is. Oh, it is from you, from NASA. And the projections are one billion and 79 million in the document. I will share this with you——

Mr. O'KEEFE. Yes, sir. No, I——

Chairman BOEHLERT [continuing]. If you are not familiar with it.

Mr. O'KEEFE. I suspect that what that also covers—I am not familiar with exactly the document you are looking at——

Chairman BOEHLERT. It starts with 2003, 2004, 2005, 2006, 2007, 2008, 2009.

Mr. O'KEEFE. Right. Let me reconcile that for the record for you.

Chairman BOEHLERT. Okay.

Mr. O'KEEFE. And because, again, the exact direct cost on return to flight still is in that range of 450. The out-year cost to—for example, the longer-term implications of creating the NASA Engineering and Safety Center and so forth, that is all additive to it, and I suspect that that is what—but let me reconcile those two numbers for you.

Chairman BOEHLERT. That would be helpful, because——

Mr. O'KEEFE. Yes, sir.

Chairman BOEHLERT [continuing]. You can see, obviously, you know where we are coming from.

Mr. O'KEEFE. Yes, sir.

Chairman BOEHLERT. We want to get it as precise as we can.

Mr. O'KEEFE. Yes, sir.

Chairman BOEHLERT. All right.

Mr. O'KEEFE. No question.

SCHEDULE PRESSURE

Chairman BOEHLERT. And there is another question that is always on the minds of all of us and that is schedule pressures. As you know, the *Columbia* Accident Investigation Board cited schedule pressure as a contributing cause of the *Columbia* accident. Members of CAIB said the schedule pressure would likely become excessive if the Shuttle were flown more than four times a year. But the exploration initiative assumes five flights a year for each of the next five years, starting this fall, and we are beginning to appreciate that it might be some slippage with that. Isn't that guaranteed to create undue schedule pressure? And how will you prevent undue pressure from developing? Will NASA be hiring more personnel to accomplish five missions a year?

Mr. O'KEEFE. Yes, sir. No, thank you for the question. The objective is to complete assembly of the International Space Station by the end of the decade. The President was very specific in the Directive in, you know, determining it as the objective, the milestone is

to complete assembly of the Station. We project that that is going to run four to five flights per year and are anticipating as many as five. The approach we have got to look to now is two things, the two drivers on the schedule that I have seen. Number one is not only the systems integration challenge of when do you send the components and the modules, but also how do you have a spacing in between them that is sufficient to provide for a launch of the next vehicle in time to assure safe haven requirements while folks have been aboard Station, should there be any problem on the prior mission. So the combination of both of those is going to give us that answer rather than what the current schedule says. And we are still working that through to figure out precisely what that will entail.

Chairman BOEHLERT. Let me ask you this. It—is it still the operating assumption that you will be able to return to flight by September or are—is there some cause to pause and rethink that very ambitious schedule?

Mr. O'KEEFE. Yeah, based on the information I have seen just in the last 10 days and reviewed now a couple of times, there are two items that now make that prospect very low. The first one is the external tank. The determination by an external panel, a group of folks and the Stafford Covey Task Force, was to expand the coverage of the insulation area from 67 degrees off centerline to 80 degrees. What that means is you are now looking at a wider area that needs certification from debris coming off of the insulation from the external tank. The second one is the actual development of the imaging capacity on the boom that we are developing and have never tested is continuing to have issues that are not insurmountable, but they may take longer. So I have my doubts, and I do not believe that the September/October time frame will be met. I think it is more likely we are going to push that to the right, and we determine that conclusively next week on how we would revise that schedule.

Chairman BOEHLERT. Well, that is a good news and bad news response. I mean, the bad news is, obviously, we can't do something we hoped to be able to do by a certain time period, but the good news, from my perspective, is that you are not so arbitrarily committed to a specific date that you will let the pressure of meeting that date overturn good judgment. And you are going to—that is good news.

OSTP EFFORTS IN THE INTERAGENCY DELIBERATIONS

Now let—the final question I have, and then Mr. Rohrabacher will have one more and maybe Mr. Lampson and—because we have to get out of here. The final question I have is for Dr. Marburger. When you participated in the interagency deliberations that led to the development of this new initiative and the vision by the President and the Administration, you were, I hope, representing all science and not just the interest of science within NASA. In other words, I hope you were operating from the perspective of the bigger picture, focusing, obviously of necessity, because of the assignment, on the program within the agency. But there are all of us up here who are concerned about the impact on science overall. That is a

concern that I know you share. And so would you address that question, please?

Dr. MARBURGER. Yes. First of all, it is my responsibility to be concerned about all of science. The vision that the President set forth is a vision that extends long into the future. And I believe that the way this vision is structured is good for science. It establishes a framework that is independent of a specific scenario or a single project that has to be accomplished in a certain time frame that actually reduces the risk of invading science budgets in the future. This is a—this provides more predictability. It provides a better framework for planning for all of science. And I particularly like the aspect of this vision that joins robotics and human exploration in a rational, balanced approach so that the scientific goals associated with this vision, in my opinion, are stronger than they have ever been in NASA. Integration of science with human exploration is a very important feature of this. So in—I think that in the long run, to embark on this course is actually better for science than what we had before.

Mr. LAMPSON. Mr. Chairman?

Chairman BOEHLERT. Mr. Lampson.

Mr. LAMPSON. Thank you, Mr. Chairman.

I am still concerned about the Iran Nonproliferation Act. And knowing that——

Chairman BOEHLERT. We were honoring the—alternating back and forth. Come on. You have a question, if you have an opportunity.

Mr. ROHRABACHER. I am sorry. I have got a plane in Dulles that I have got to run out for, and—yeah, I—thank you very much, Mr. Chairman.

RTF DELAYS AND THEIR EFFECT ON THE BUDGET

First and foremost, how will the Shuttle delays that you just mentioned affect the rising cost in—for your budgets for fiscal year 2005 through 2009?

Mr. O'KEEFE. I can't make an assessment right now, but I don't think this is going to be a cost-driver. It is more a technical driver on the two—the external tank as well as the imaging boom, neither of which appear to be cost-drivers, and they are more just technical development questions. So I don't anticipate a big cost differential here.

Mr. ROHRABACHER. But just the time will cost money, will it not?

Mr. O'KEEFE. Sure, by definition, but, you know, we are not talking about—we are not—it is single-digit months, not years.

Mr. ROHRABACHER. Okay. So number one—number two, let me just note, for the record, that as far as I am concerned, and I think a large number of people are concerned, because we are on budget constraint, we are worried about science programs being cut, anything that can be done commercially that will be—that will make it cheaper to achieve our goals in space, especially those concerning Station, should be done, because that leaves more money available for science projects and other projects. And also—and that includes the servicing of the Space Station, which there are alternatives—private sector alternatives that have been offered, and if they can be—if they are cheaper, they should be done.

And finally, I guess we have talked about the pursuing of commercial interests, so that is just about it.

Mr. O'KEEFE. Thank you, sir. Yes, sir. I understand——

Chairman BOEHLERT. And have a great flight, Mr. Rohrabacher——

Mr. ROHRABACHER. Thank you.

Chairman BOEHLERT [continuing]. The very distinguished Ranking Member of the Committee on Space and Aeronautics.

Mr. Lampson.

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Mr. LAMPSON. Thanks, Mr. Chairman.

Just a quick statement about the INA that I still concern myself with. Mr. Rohrabacher made the comment earlier on his first time around about the exception for imminent danger that we can, indeed, deal with the Russians under those circumstances. There presently is not an imminent danger. And the concern is that we only have Soyuz that are going to be built, I think, two under construction, and soon we will not have anything there if—and even though we are involved with discussions with our ISS partners, current law tells us we can't do it with the Russians. And there is pending legislation that would allow us to solve that problem, give the President the flexibility necessary, NASA the flexibility necessary to do these negotiations. It just doesn't make sense that we are not looking at those opportunities, and it seems to me that we are going forward without a good plan with a major initiative here. And I yield my time to Mr. Gordon.

VISION COST

Mr. GORDON. Excuse me. A quick, final clarification. The post-2009, that period for the lunar/Mars, that looks to me like about $150 billion. Does that sound about right to you?

Mr. O'KEEFE. Well, sir, I would have to go back and take a look at the numbers. I really can't offer it off of the top of my head. I am sorry.

Mr. GORDON. Okay. But you are going to do that, though, right?

Mr. O'KEEFE. Yes, sir. Yes, sir.

Mr. GORDON. And I—and the final thing is, that is what you are allocating. And I assume that what you are allocating and what you think is necessary to complete the mission is the same thing?

Mr. O'KEEFE. No, sir. What is occurring in 2009 and out is a projection of what the transition, the transformation of the approach that we are taking here would import if you compare it to the annual cost of an inflation level increase to the annual top line. That is all that this attempts to do, but I will try to parse that——

Mr. GORDON. Okay. So is that—and again, just for me, so that—does that budget, then, get us to the Moon or not?

Mr. O'KEEFE. It is not a budget. It is a projection.

Mr. GORDON. Okay.

Mr. O'KEEFE. The only budget before you is 2005 through 2009.

Mr. GORDON. Okay. Does that projection try—is that projecting what it is going to cost to get us to the Moon?

Mr. O'KEEFE. No, sir, it does not.

Mr. GORDON. Then why are you doing it, then? What is the benefit of it?

Mr. O'KEEFE. To demonstrate, as we continue this particular approach of, again, building on the successes at each successive stage, is there some balloon note beyond 2009. And the answer is no, based on this approach. At the concurrent time in which you are seeing at retirement of Shuttle, you will see an acceleration of the development on the Project Constellation crew exploration vehicle, the development of the human and robotic technologies——

Mr. GORDON. Okay.

Mr. O'KEEFE [continuing]. All of that——

Mr. GORDON. But you don't know what you get, though?

Mr. O'KEEFE. Yes, sir, we could walk through that, but there is——

Mr. GORDON. Okay.

Mr. O'KEEFE [continuing]. No pretense of precision of program numbers out through 2020 that would give you that level of granularity to say this is the cost of that——

Mr. GORDON. Okay.

Mr. O'KEEFE [continuing]. Broader set of mission objectives. It is going to be a combination of all of them and depending on which sequence you pursue.

Mr. GORDON. Okay. Thank you.

Mr. O'KEEFE. Thank you, sir.

Chairman BOEHLERT. I thank you. And now, as Martin Agronski used to say for the final word, Dr. Ehlers.

CENTRIFUGE

Mr. EHLERS. If I were to find a word, I think everyone in the room would be overjoyed.

I do want to thank both of you for being here and to sympathize with—yesterday, I sympathized with the panel who was being asked tough questions here, including Dr. Marburger. Today, I sympathize with you in a deeper sense, because you have a very, very tough job ahead of you. As science is always difficult, but when you are doing it to this extent, it is also very expensive and a lot of dollars riding on the decisions you make everyday. So I express my appreciation for you, but also my sympathy.

All right. I want to ask a specific question about what I understand as a problem on the Space Station of a very crucial component. Mr. O'Keefe, you mentioned the purpose—primary scientific purpose at this point is the study of the human effects of long-term space flight. And I understand a very important part of that is the Japanese centrifuge portion of the Space Station. I also understand that that is in trouble and that you have been giving them some help, but that it is behind schedule, it may not be ready to launch. The first question is, will it be ready to launch before you discontinue the current Shuttle? And secondly, what is the problem? Is it serious? Can it be remedied? And will they meet their timetable?

Mr. O'KEEFE. Yes, sir. Our Japanese partners have been examining a cost challenge that they are having with development of the centrifuge. It was due to be delivered and launched, I believe, in 2008, and we are going to be examining that again, beginning

today through these next several weeks, to look at what the sequence of that may mean on the schedule itself. But what the cost is to them and what they may be experiencing in terms of overrun are their responsibility, but in terms of the actual delivery date of the module, that is the point we will need to continue to work through.

Mr. EHLERS. Are you confident it will be ready to fly before you discontinue the Shuttle?

Mr. O'KEEFE. It appears that way, but again, there may be tradeoffs of what we may come to based on the ultimate configuration of Station, which may call for other modules or components to be considered. But that is part of what we are going through here in this current set of meetings that are convening today and going through the next several weeks and will continue on.

Mr. EHLERS. Is—am I correct that that is a very crucial component if you really want to examine the effects of low gravity?

Mr. O'KEEFE. Let—I am going to let Dr. Marburger comment here in just a second, but I am told that the approach that is taken depends really on the kind of experimentation you are looking for. And the—it essentially simulates a gravitational condition.

Mr. EHLERS. Yes.

Mr. O'KEEFE. So it therefore reverses the effects of what——

Mr. EHLERS. Right.

Mr. O'KEEFE [continuing]. We are trying to understand about living in micro-gravity conditions.

Dr. MARBURGER. I will just say a technical word. The point of the centrifuge is to be able to tune the gravity from——

Mr. EHLERS. Right.

Dr. MARBURGER [continuing]. Zero up to some value that the centrifuge is capable of. The unique thing about the Space Station environment is it has zero gravity. We can not achieve that on Earth for long periods of time, so the availability of zero in that parameter is—already suggests a lot of experiments you can do, even if you can't tune all of the way through the spectrum of values that gravity could have.

Mr. EHLERS. Yeah, but I assume that we already knew a great deal about the effects of zero gravity on humans, because we had the Mir Space Station and Skylab. People have been up there for many——

Dr. MARBURGER. Not all of those experiments were designed to get the kind of biomedical information that you can have, and many of them were done in an era where we knew much less about how the body works. We are in a much better position today to understand these problems scientifically than we were even a few years ago. So the—I believe that one of the values of focusing research is, in fact, to have a much more deliberate progress toward understanding these effects.

Mr. EHLERS. Can you give me an example of something that we can do now that we had no idea we needed to do before? I am just surprised we couldn't do better before.

Dr. MARBURGER. Well, the way the systems of the human body work have benefited from these very large investments we have made in biomedical research for the last 10 years. And we understand them much better now. I might add that NASA works very

closely with NIH in developing strategies for doing this work, and it would be surprising if there weren't important developments that we can take advantage of. But the—you know, the objectives of many of these past missions were not only focused on weightlessness issues.

Chairman BOEHLERT. Thank you very much.

And that was the final——

Mr. O'KEEFE. I am sorry, Mr. Chairman, just very short.

Chairman BOEHLERT. Ten seconds.

Mr. O'KEEFE. There is the National Academy of Sciences study just released here on medical effects on astronauts that—and cosmonauts, based on the limited information we have there. We are only three years into continuous presence. Our longest duration space flight, on Station, is 196 days. That is it. So the cohort is pretty small in trying to make determinations here.

Chairman BOEHLERT. Thank you very much. And I think, as we conclude, it should be evident to all concerned in this very substantive probing analysis and exchange that costs are a major consideration, and there is a lot of uncertainty about the cost. And the chart, while attractive, leaves some questions for all of us.

This is not the beginning of the end, this is the end of the beginning, and we will have more substantive hearings, like this one, as we move forward together and try to identify with shaping of the best possible responsible policy, not just for NASA, but for the Nation.

Thank you very much. Hearing adjourned.

[Whereupon, at 12:46 p.m., the Committee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by John H. Marburger, III, Director, Office of Science and Technology Policy, Executive Office of the President

Questions submitted by Chairman Sherwood Boehlert

Q1. Through its Earth Science programs NASA funds a significant share of the federal global change research budget. But to help pay for the President's exploration proposal, the NASA budget proposes to cut Earth Science by about three percent below the amount appropriated for the current year. This would mean canceling a number of projects, such as the Ocean Winds mission, an Ozone measuring mission, and deferring other projects, such as the Global Precipitation Monitor. How will these cuts and delays affect the implementation of the global change program's newly developed plan? To what extent did you consult with other partners in the global change research program before proposing these cuts?

A1. There is nearly $1.5 billion requested for NASA's Earth Science programs in the FY 2005 President's Budget. NASA's Earth science program will continue to provide key data sets and building blocks required for climate science and a comprehensive Earth observing system. Funds support new research-oriented missions to measure ocean salinity, carbon dioxide concentration, and aerosol concentrations in line with the Climate Change Strategic Plan. In addition, funds are provided to ensure the continuity of Landsat data, as well as test critical sensors on the next-generation of operational Polar orbiting satellites, both of which are key components of our Earth observing infrastructure. In the few instances where missions were deferred and/or canceled, the decision was made that delaying the availability of specific data sets would not unduly impede scientific progress.

The Global Precipitation Mission (GPM) will be deferred two years. This is a new data set, so there are no data continuity issues, although it does build on the data established from NASA's Tropical Rainfall Measuring Mission launched in 1997. The GPM data is expected to advance our understanding of the water cycle, which is why the Administration remains committed to the mission, as well as to continuing our partnership with the Japanese.

Ocean Vector Winds, a canceled mission, was designed to ensure data continuity in wind surface measurement during the anticipated gap between the Japanese Midori II Spacecraft and the National Polar-orbiting Operational Environmental Satellite System (NPOESS). However, the Midori II recently failed, and due to previous ocean wind mission failures, the historical data record has numerous gaps. While such missions provide an important variable for understanding patterns in weather and climate, the Administration believes that ensuring the near-term continuity of other parameters is of greater scientific importance. Systematic collection of the ocean winds data set will become an operational endeavor with the first flight of the NPOESS program in 2010.

Q2. Much of the President's vision for space exploration begins in earnest after 2010, when we finish the Space Station and retire the Shuttle. How significant a factor were the agreements we have with our international partners in the Administration's decision to continue the Space Station even until then?

A2. Consideration of the interests of our international partners was a significant factor in the discussions on ISS. Several other important factors were considered, including the ISS's unique capabilities to support research on understanding and countering the impact of the space environment on astronaut health. The commitment to the international partners was acknowledged as important in the President's speech on January 14, 2004, when he stated, *"We will finish what we have started, we will meet our obligations to our 15 international partners on the project."*

Q2a. If we did not have these international agreements, would the President have proposed completing the Space Station?

A2a. As mentioned above, the commitment to the international partners was an important consideration—but not the only one.

Q3. The President's "Vision" document lists "advanc[ing] security" as a fundamental goal of the exploration initiative. In what ways will the initiative advance security? Are there any projects that will be designed in a particular way to further security goals? Does the goal of "advancing security" conflict in any way with the stated intention to make the exploration initiative an international effort?

A3. Enhanced security will be an indirect consequence of the implementation of the President's vision. For example, the vision provides focus to the civilian aerospace sector which should lead to a more coherent investment strategy. The vision should also stimulate more citizens to maintain an interest in science, math, and engineering. And some of the technologies developed (e.g., enhanced human-machine interface and robotics) should have "spin-off" applications to the national security sector. In addition, some development programs to support the vision may directly benefit both the civil and national security space sector. Such programs could include new heavy lift launch capability or the ability to deploy large arrays in space. There should be no conflict with the intention of making the exploration initiative an international effort. Export control issues will, of course, need to be addressed as they arise.

Q4. Does it adversely affect the U.S. if other nations have humans in space and we don't? In what way? What advantages are the Chinese likely to gain from their human program other than proving they can do something the U.S. has already done?

A4. In the short-term, not having a human space flight program would have an intangible impact that would likely affect many people. That impact could include a sense that the U.S. had lost its technological leadership. The average person still views the Apollo landing as one of the crowning achievements of our society and an accomplishment that will long be identified with the U.S. In the longer-term, the loss of human capability in space will limit our ability to conduct more ambitious and complex exploration activities. Leveraging human cognitive ability on site with robotic and tele-operated systems is likely to offer the greatest reward in discovery. In terms of the Chinese space flight program, it's premature to predict advantages the Chinese are likely to gain.

Q5. You were quoted in Science *magazine as saying "The vision has greater scientific significance than past missions—and science will be more productive with it than in its absence." Can you give us some specific examples of how the initiative will increase the productivity of science?*

A5. The President's new paradigm will open up opportunities to explore and understand the cosmos that are not technically possible today. During the first 40 years of NASA's exploration of the solar system, the available technology and resources have allowed for flyby missions of numerous moons, asteroids, comets, and every planet except Pluto. In a few cases, orbital missions were executed (the Moon, Venus, Mars, Jupiter, and the asteroid Eros) and in even fewer cases, landings were made (the Moon, Venus, and Mars)—and only the Moon has had a sample return to date.

During the same period, space observatories have become increasingly more sophisticated, opening up windows of observation that are impossible from the ground. Data from these facilities have transformed our understanding of the formation and evolution of the Universe.

Further major advances in understanding the Solar System and the universe will likely require even more complex operations in space or on the surface of solar system objects. These would involve high power instrumentation, large area and long-duration investigation of multiple planetary bodies, and the possible assembly of sophisticated observatories.

Such complex missions are not possible today for several reasons, including: the small payload mass we can affordably send into deep space; limitations in power due to decreasing solar flux at high latitudes on near planets or deeper into space; slow communications data rates to Earth; and the challenge of programming autonomous missions and controlling operations from Earth, given the large time delays imposed by the speed of light.

These "infrastructure" issues are inter-related and their resolution will provide the backbone for a robust exploration agenda—an agenda that allows for close-in examination, the ability to touch the item under scrutiny, and the evaluation of large area and long-term trends.

The President's vision and its budget call for the deliberate development of the capabilities needed to open up the Universe to increased scrutiny. It will create new transportation options for both robots and humans, harness the natural resources found in space to foster sustainability, develop robust high power systems, improve communications, and build vastly more capable robots and improved robotic-human interfaces.

Q6. Are there any scientific objectives related to the Moon that require a human presence? If not for the proposed human landing, how high a priority would a lunar

robotic mission be? How many of these missions would be launched? Why have lunar missions rarely appeared as a top scientific goal in National Academy of Science studies or NASA's own plans?

A6. The President's vision calls for undertaking lunar exploration activities to further science, to test out new technologies and techniques, and to develop key capabilities to support more distant, more capable, and/or longer duration human and robotic missions. It may also be necessary to have humans on the Moon to "oversee" robotic systems involved in the construction of complex devices—whether for *in situ* resource utilization or a deep space observatory. The presence of humans should also *enhance* scientific missions as noted by the National Academy of Sciences over the years. For example, the Apollo rovers (man-piloted) typically traveled 30 km in a three-day period (average of 10 km per day). That was accomplished 30 years ago. Today, the Mars Rovers (tele-operated) travel tens of meters per day. So mobility is enhanced with direct human oversight. Humans are also better able to quickly identify anomalies in the background and focus on areas of high interest.

In terms of science and exploration, the Moon has roughly the same surface area as the continent of Africa—yet remains largely unexplored. The total time that humans have spent on the surface of the Moon is about 300 hours—or about 12 days. Going back to the Moon will help to resolve open issues about the formation of the Moon, its cratering history (used to date events throughout the solar system), and the lunar bulk composition across the surface and at depth. Since the lunar surface has remained relatively unchanged for billions of years, it is also hoped that the Moon can supply important information on how the inner planets formed and evolved. For example, we only have accurate crater dates of the areas where samples were collected. These indicate that those regions were formed within a narrow time interval about 3.8 billion years ago. Extending this result to other regions of the Moon has important implications as to the history of these cataclysmic events and, by extrapolation, how it affected the Earth's history.

The National Academy of Sciences Space Studies Board's recent report, *"New Frontiers in the Solar System: An Integrated Exploration Strategy,"* recommended that NASA initiate a sample return mission from the Moon. Specifically it advocated studying the Aitken Basin region of the lunar south pole which is the largest known impact crater in the solar system and may also represent one of the oldest and deepest craters on the Moon.

Questions submitted by Representative Bart Gordon

Q1. What did the President ask you about the costs of the President's space initiative, and how did you respond?

A1. The President considered cost parameters; however, as you know, it would be inappropriate to provide details of discussions held during the deliberative process. The budget "sandchart" was considered and background data supporting it were developed during this process. The "sandchart" delineates the distribution of the $87 billion that makes up the President's FY 2005–FY 2009 budget submission. It further shows a notional distribution of funding within NASA for FY 2010–FY 2020, assuming an increase to the NASA budget roughly consistent with inflation. The total notional budgetary estimate for NASA during FY 2010–FY 2020 is shown on the chart as $228 billion. Of this total, approximately $143 billion is estimated for human and robotic exploration (including the CEV) and approximately $85 billion is estimated for the ISS, ISS transport, Shuttle, and non-exploration portions of NASA budget (such as aeronautics).

Q2. In 1989, President George H.W. Bush proposed an initiative similar to that being proposed by his son, President Bush—returning humans to the Moon and eventually going on to Mars. To quote from a 1992 Congressional Research Service report: "At the time of President Bush's original speech, however, Richard Darman, Director of OMB, estimated that it would cost $400 billion over 30 years." *That works out to about $590 billion in today's dollars.*

Q2a. Is there any reason to believe that wouldn't be a reasonable estimate for the cost of the President's proposed initiative?

A2a. The President's proposal presents an appropriate approach to our nation maintaining its leadership role in space, and the cost you mention is not a reasonable estimate. The budget estimate for the Space Exploration Initiative (SEI) assumed a particular approach to Mars exploration that is no longer being considered. The SEI reference architectures assumed extensive infrastructure and are described in the 1989 "Report of the 90-Day Study on Human Exploration of the Moon and

Mars." In this report, NASA estimated the cost of two of the architectures as approximately $470 billion and $540 billion over a 35-year time horizon. The estimated cost to establish a lunar outpost was about $100 billion and about $158 billion for establishing the Mars outpost. The rest of the budget was for further base extension and operations. Thus, achieving a permanent presence on the Moon and an outpost on Mars, without the long-term operational costs, was estimated at $258 billion.

The SEI architectures assumed significantly more extensive and complex infrastructure than is assumed today. As two examples of major differences in the architectures between SEI and the President's proposal, consider the reference space transport infrastructure and the role of the Space Station. The SEI assumed that the Space Shuttle would continue to fly indefinitely and would be used to transport crew from Earth to the Space Station. *In addition,* a separate heavy launch vehicle (about 60 metric tons) would be developed to support the lunar missions. Yet another, even larger, heavy launch vehicle (about 140 metric tons) would be developed to support the Mars missions. Given the tight time lines on the SEI, the development cost for both of these heavy launch systems plus the operational costs of continuing the Space Shuttle were concurrent expenses. Furthermore, both new launch vehicles required enhancement to the ground launch and production facilities. As a second example, consider the role of the Space Station. SEI assumed an evolvable space station that would be the location for on-orbit assembly of vehicles, serve as the transportation node, and allow for refurbishment of the vehicles upon their return. This envisioned space station would evolve through four configurations *beyond assembly complete* that would ultimately accommodate 12 permanent crew members plus an *additional* transient crew of four. It would also contain enclosed vehicle hangers and an assembly facility. This role for the Space Station is well beyond that planned in the current vision, which calls for focusing the Space Station on research relevant to the exploration initiative.

The cost of the space initiative will be strongly dependent upon the architecture. To demonstrate how much the cost is dependent upon the specific architecture, consider the Lawrence Livermore concept *"The Great Exploration,"* that was proposed around 1990 as an alternative to the SEI. *The Great Exploration* program provided for permanent bases on the Moon and Mars within ten years of initiating the program and with an estimated cost of $40 billion. *Greater than a factor of ten* difference in cost estimate between SEI and *The Great Exploration* was due to the assumed development, risk, and infrastructure.

Q2b. Do you have a better estimate that you can share with this committee?

A2b. As illustrated in the answer above, cost estimates for human missions to the Moon and Mars are very sensitive to the architecture. The cost estimates are also sensitive to the timeframe chosen, since the initial costs of establishing a human presence on the Moon or Mars is only one component of the cost if along-term human presence is desired. For the SEI architectures described above, roughly 50 percent of the cost was for establishing an initial capability on the Moon and Mars and the remaining 50 percent was for expansion and operational costs. We do not yet have a defined architecture. Nor do we have a detailed timetable for getting to Mars. Thus estimating the cost of establishing a presence on the Moon and Mars (to compare with SEI) would involve a great deal of speculation. Much of the large range in costs between the estimates for SEI and *The Great Exploration* (described in the answer above) can be attributed to the very different mass estimates assumed. Some of the technical challenges for NASA are therefore to decrease the mass required to support humans (such as developing high efficiency life support systems), to utilize in-space resources to decrease mass launched from the Earth, and to lower the effective transportation costs (such as prepositioning cargo utilizing lower cost launches).

The goal of the President's vision is, however, about more than a mission to the Moon and Mars. Ultimately the vision is to advance U.S. scientific, security, and economic interests, to explore the solar system and beyond, and to extend human presence across the solar system. The vision does not have an end date—as the President stated on January 14, we will continue to make progress "one mission, one voyage, one landing at a time." As such, it is not possible to assign an "overall cost" to the vision. The strategy, instead, is to maintain a stable budget for NASA to enable long-term planning and to be responsive to both challenges and opportunities not yet understood. The emphasis shifts from budgeting to reach a specific destination, and instead, seeks to maximize the progress and opportunities given a specific budget. Unlike previous major civil space initiatives, the approach is intentionally flexible, with adjustable exploration milestones to maintain affordability. This approach places a premium on avoiding balloon payments for future Congresses, Administrations, and taxpayers.

Q3. How much do you estimate it will cost to achieve a human lunar landing by 2020, and what assumptions are included in that estimate?

A3. The human lunar landing is only one element of the new vision, so it is difficult to try to extract the costs of that one milestone from the overall cost of the vision. Should the development of a new heavy-lift launch vehicle—one that would also be useful for a Mars mission and potentially for future commercial or defense missions—be included in the cost estimate for a first human lunar landing? Should the lunar robotic missions that conduct science and explore as they set the stage for human landings be included? What about the technology development that enhances the capabilities of those robots?

In response to Congressional inquiries, NASA did attempt to determine what the cost of a human lunar mission would be, through 2020, if conducted in a mode similar to the Apollo program. That estimate is $63 billion. However, that estimate does not reflect new architecture studies or design analysis. Nor does it include potential benefits from new technologies or innovative approaches yet to be undertaken. It also does not include the robotic precursor missions that will do science and perform risk reduction activities applicable to the broader exploration vision. The estimate assumes:

- Lunar lander ($12 billion)—based on similar Apollo lunar lander.
- Launch vehicle ($15 billion)—assumes development and production of a new 100-mT Saturn V-class vehicle. Estimate based on scaling EELV parametrically is $13 billion. Similarly, recent Marshall Spaceflight Center studies estimate $2–13 billion development depending on number of new engines, stages, and facilities. Approximately $3–4 billion of total is for production.
- Crew Exploration Vehicle development and operations ($24 billion)—this includes $15 billion for development and $9 billion for operations.
- Operations ($10 billion)—first landing by 2020. Costs comparable to Apollo.
- Other ($2 billion)—funding available for follow-on mission hardware and reserves.

Questions submitted by Representative Nick Lampson

Q1. In order to fund the President's initiative, cuts, deferrals, and cancellations will be made to a wide range of NASA programs.

Q1a. Did you offer to make such cuts in order to fund the President's initiative, or were you directed to make such cuts? If the latter, who directed you to make them?

A1a. NASA, working with OMB, used the new vision to prioritize ongoing activities and to fit within a top-level agreed upon budget. Some near-term decisions were readily apparent (e.g., canceling the Orbital Space Plane) while others are still being assessed (e.g., specific research projects within the Office of Biological and Physical Research). The new vision provides the needed context to assess the relative priority of projects and to make difficult, yet necessary, decisions. In most cases, the impact on the science missions was negligible. In the few cases (e.g., the proposed dark energy probe), OSTP is working directly with OMB and NASA to reduce the impact.

Q1b. Why are the science and aeronautics programs that have been cut, deferred, or canceled considered a lower priority than the President's Initiative?

A1b. The space exploration vision provides the overarching focus for the civil space exploration program. Research efforts that do not directly support enabling the vision remain important and have been appropriately prioritized. In a fiscally constrained environment, hard choices need to be made to ensure that sufficient resources are available to execute the primary vision, as well as the important science projects. This is a hallmark of leadership. Furthermore, only a handful of current science programs have been cut, deferred, or canceled. No aeronautics programs were cut as a result of the new vision. The majority of the cuts have come from within the human space flight portfolio and much of the remainder is from slowing the rate of growth in the budgets.

Questions submitted by Representative Mark Udall

Q1. In your written testimony, you cite the failure of the NRC's 2001 Decadal Survey to recommend new missions in the Hubble wavelength regime as a scientific ra-

tionale for not pursuing the SM–4 HST servicing mission. However, isn't it true that the Decadal Survey assumed that the Hubble Space Telescope would continue to operate until the end of this decade and that it endorsed NASA's decision to continue HST operations through this decade? If this is true, why do you cite the Decadal Survey?

A1. The Decadal Survey did assume that Hubble would continue to operate until the end of this decade. This point was mentioned in my written testimony where I stated, *"The committee wrote its report assuming the SM–4 service mission would take place, but its statements regarding the evolving role of the Hubble relative to other priorities are important in the present discussion about risk versus benefits."* My point in citing the National Research Council was to highlight that the future space science objectives were shifting to other wavelength regimes. This is relevant when objectively evaluating the benefit with the risk. I am pleased that the National Academy will specifically address the Hubble servicing issue, and I look forward to their assessment of options and recommendations.

Q2. What countries have been approached about their willingness to participate in the new human space flight vision? What have their reactions been? What additional countries do you intend to approach? What is the U.S. government's current position on whether China is eligible to participate in significant human space flight activities with NASA? Would you in fact welcome China's participation in this initiative?

A2. In announcing the Space Exploration Vision, President Bush said: "The vision. . .is a journey, not a race, and I call on other nations to join us on this journey, in a spirit of cooperation and friendship." Following up on this invitation, NASA has initiated a dialogue with the current International Space Station partnership consisting of 15 foreign countries. While this dialogue is only beginning, many of the partners have indicated a great deal of enthusiasm and interest in participating in executing this long-term vision. Participation in executing the vision is not limited to the Space Station partners alone. The participation of each country, including China, will be evaluated on an individual basis, taking into account both the experience of the country and the bilateral relationship.

Q3. What is the scientific rationale for the President's initiative? How much of that rationale will be satisfied by planned robotic missions, and how much will require human explorers? From a scientific standpoint, what objectives specifically require human explorers?

A3. The President's new paradigm will open up new opportunities to explore and understand the cosmos that are not technically possible today. During the first 40 years of NASA's exploration of the solar system, the available technology and resources have allowed for flyby missions of numerous moons, asteroids, comets, and every planet except Pluto. In a few cases, orbital missions were executed (the Moon, Venus, Mars, Jupiter, and the asteroid Eros) and in even fewer cases, landings were made (the Moon, Venus, and Mars)—and only the Moon has had a sample return to date.

During the same period, space observatories have become increasingly more sophisticated, opening up windows of observation that are impossible from the ground. Data from these facilities have transformed our understanding of the formation and evolution of the Universe.

Further major advances in understanding the Solar System and the universe will likely require even more complex operations in space or on the surface of solar system objects. These would involve high power instrumentation, large-area and long-duration investigation of multiple planetary bodies, and the possible assembly of sophisticated observatories.

Such complex missions are not possible today for several reasons, including: the small payload mass we can affordably send into deep space; limitations in power due to decreasing solar flux at high latitudes on near planets or deeper into space; slow communications data rates to Earth; and the challenge of programming autonomous missions and controlling operations from Earth, given the large time delays imposed by the finite speed of light.

These "infrastructure" issues are inter-related and their resolution will provide the backbone for a robust exploration agenda—an agenda that allows for close-in examination, the ability to touch the item under scrutiny, and the evaluation of large-area and long-term trends.

The President's vision and its budget call for the deliberate development of the capabilities needed to open up the Universe to increased scrutiny. It will create new transportation options for both robots and humans, harness the natural resources

found in space to foster sustainability, develop robust high power systems, improve communications, and build vastly more capable robots and improved robotic-human interfaces.

The vision does not artificially separate the role of humans and robots in enabling this new capability—but assumes that the strengths of each will be used to achieve the stated mission.

Questions submitted by Representative Zoe Lofgren

Q1. In NASA's document "The Vision for Space Exploration," the goal of the President's initiative is stated as follows: "The fundamental goal of this vision is to advance U.S. scientific, *security,* and economic interests through a robust space exploration program." *I am very confused by the wording of your statement. You do not refer to U.S.* geo-political *interests, which motivated President Kennedy and the Apollo program. You do not refer to U.S.* diplomatic *interests, which motivated President Clinton to reach out to Russia as a partner in the International Space Station. You refer—repeatedly—to U.S.* security *interests. For those of us committed to the peaceful explorations and uses of outer space, this language is troubling.*

Q1a. Please explain how this new space vision will contribute to the security *interests of the United States. Please be specific and try to avoid general statements about how the initiative will have undefined economic spin-offs.*

A1a. The Space Exploration Vision as outlined by President Bush is a civil initiative but has the potential to enhance U.S. national security also. The implementation of the vision will contribute to U.S. scientific and technological leadership; inspire more citizens to study science, math, and engineering; and will likely advance robotics, human-machine interface, applications of nanosystems, and other technologies that are likely to have "spin-off" applications to national security and commercial enterprises.

Meaningful cooperation with other countries in executing the vision also will contribute to advancing U.S. foreign policy interests. Further, the inspiration provided by space exploration has a profound positive impact on the hearts and minds of people around the world.

Q1b. Will the Department of Defense be involved in the Moon–Mars initiative? If so, how?

A1b. The space exploration vision is an inherently peaceful scientific endeavor. In executing the vision, NASA will cooperate with the Department of Defense in the development and use of space transportation capabilities—particularly the Evolved Expendable Launch Vehicles—and will continue to rely on the Department of Defense's space tracking and surveillance capabilities.

Q1c. Can you give me your commitment that this new initiative will not contribute in any way to the placement of weapons in space?

A1c. The space exploration vision is an inherently peaceful scientific endeavor.

Question submitted by Representative Brad Sherman

Q1. According to NASA's budget plan, the President's exploration initiative is estimated to cost close to $200 billion over the next 15 years, with more costs incurred after that time. Why is this investment better than investing the same amount of money in energy R&D, with the goal of making the U.S. energy independent? Which of the two alternative investments do you think would deliver a greater benefit to the American economy and to overall societal goals?

A1. Both space exploration and energy R&D are important issues and both will return different benefits to the American economy and to society in general. The President's FY 2005 budget includes the resources necessary to aggressively pursue both topics in a manner that is prudent and sustainable.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Sean O'Keefe, Administrator, National Aeronautics and Space Administration

Questions submitted by Chairman Sherwood Boehlert

Q1a. Please provide the key milestones (e.g., Systems Requirements Review, Preliminary Design Review, Critical Design Review, etc.) along with associated dates through the first launch for the following initiatives: the lunar robotic mission planned for 2008; and

A1a. The details of these missions are still being developed, but here is a preliminary schedule thus far:

Lunar Reconnaissance Orbiter (LRO)

Release of AO for payload 06/04
Receipt of Proposals for Peer Review 09/04
Payload Selection 11/04
Begin Phase A/mission definition 01/05
Systems Requirements Review 03/05
Preliminary Design Review 05/05
Critical Design Review/Confirmation 04/06
LRO Pre-Ship Review 07/08
LRO Launch Readiness Review 09/08
LRO Launch 10/08
Arrival at Moon 10/08
Nominal Measurement Mission 11/08–12/09
(+ goal of up to five-year extension)

The first human mission to the Moon is currently planned for the 2015–2020 timeframe. This mission is highly dependent upon the outcomes of our robotic missions and the development of the Crew Exploration Vehicle; therefore, it is too early in the process to provide details. NASA will of course keep the Committee apprised of our progress toward this goal.

Q1b. Please provide the key milestones (e.g., Systems Requirements Review, Preliminary Design Review, Critical Design Review, etc.) along with associated dates through the first launch for the following initiatives: the human mission to the Moon, including but not limited to the Crew Exploration Vehicle, planned for 2015.

A1b. The Office of Exploration Systems is formulating the acquisition plan for the elements of Project Constellation. The following milestones represent significant events in the next ten years towards a human Lunar mission as early as 2015. These milestones are for planning purposes only.

June 2004—Two Broad Area Announcements (BAA) for (1) Technology Maturation and (2) Concept Exploration and Refinement of the Lunar Architecture.
September 2004—Release first draft of Level I Requirements
January 2005—RFP for CEV Design, Development, and Flight Demonstrations
2006—CEV Program Initiation
2008—CEV Risk Reduction Flight Demonstration
2008—CEV Design Review—Select CEV Prime Contractor
2011—CEV Unmanned Flight Demonstration
2014—CEV Manned Flight

Q2. What alternatives exist or could be developed, if any, to the Soyuz capsule for crew-escape on the Space Station by 2006? If there are none, does the Administration believe a legislative change to the Iran Nonproliferation Act is necessary? If not, please explain the circumstances under which the Administration plans to acquire Soyuz capsules in 2006? If a legislative change is necessary, when does the Administration plan to propose such changes and what is the latest date by which Congress will need to act?

A2. At this time, NASA has not identified any alternatives to the Soyuz capsule for crew-escape on the Space Station by 2006. NASA and the Administration are aware of the provisions of the Iran Nonproliferation Act and will work with the Congress

to ensure that our strategy for procuring additional Soyuz capsules anytime in the future is sound and meets all statutory requirements. The Administration is developing its approach at this time.

Q3. If the Space Shuttle must be operated beyond 2010 for any reason, does NASA plan to abide by the recommendation of the Columbia *Accident Investigation Board and re-certify that it is safe to fly?*

What does steps would recertification involve and how much would it cost?

Does either of NASA's five-year or 20-year budget projection include funds to pay for re-certification?

A3. Yes, NASA intends to implement the recommendations of the *Columbia* Accident Investigation Board. NASA is currently reassessing the ISS assembly sequence to ensure that the Shuttle can be safely retired following assembly of the International Space Station, planned for the end of the decade. To prepare for the contingency that the Shuttle may need to operate beyond 2010, NASA is assessing the need to recertify Space Shuttle systems, subsystems, or components consistent with the Vision for Space Exploration and in line with the recommendations of the *Columbia* Accident Investigation Board. The technical work required to determine when and if recertification would be needed will continue into this summer. Once the technical definition of the recertification tasks is completed, cost estimates will be developed on the items we need to recertify and made available for discussion. NASA's budget does not include funds to pay for re-certification.

The budget does, however, include some funding to address safety-enhancing upgrades and maintenance-related component and/or subsystem recertification.

Q4. How much does NASA estimate the first mission will cost and are funds for these subsequent missions included in the budget projection NASA provided through 2020? Ref. Robotic Mission to Moon, human missions to Moon. Does the projection include funds for a lunar descent stage and ascent stage on the first human mission to the Moon? Does the projection include funds for a base of any kind on the Moon or any other infrastructure?

A4. NASA is committed to realizing the Vision for Space Exploration without substantial augmentation of NASA's existing budget. More importantly, NASA will organize its exploration program so that it does not require major new commitments of funding in future administrations. By leveraging technologies that already exist, and emphasizing demonstrated performance, NASA will ensure that investments directly lead to mission success.

Mission architecture assessments are currently in work to provide input to the development of Level I mission requirements that will be released in draft form in September 2004. These Level I Requirements and the acquisition plan for developing the element of Project Constellation are critical to the detailed assessment of cost. Budget estimates for planning purposes include multiple robotic and human missions as well as possible Lander, Descent, and Ascent Stages.

NASA is adopting an approach to vehicle and systems development based on the Defense Department's "spiral development" model. This approach emphasizes the use of existing technologies and the incremental demonstration of performance. By focusing research and test programs on rapid deployment of technologies that can be evolved, NASA will ensure that it is focused on the capabilities that are most critical to exploration rather than the most comprehensive designs that are possible. NASA's exploration programs will also employ management techniques such as earned value management, which will ensure that costs are allocated based on strict planning geared towards national priorities. Through the combination of these techniques and a commitment to managing requirements within budget guidelines, NASA will make the hard choices needed to realize the Vision for Space Exploration.

Q5. In response to questions from Congressman Bart Gordon, NASA said the Space Station research program is being re-focused on overcoming the limits to crew survivability in space due, for example, to radiation and bone loss. NASA said the budget for this program is roughly $550 million for fiscal year 2004 and will decline to $427 million by 2009.

Q5a. What is included in these estimates and how did NASA develop these estimates before developing the program's agenda?

A5a. The year-by-year ISS research funding through FY 2009 referenced in the question is an estimated projection of the ISS Research Capabilities (ISSRC) budget

through FY 2009. On completion of our pending exploration replanning, we will realign the ISSRC budget to complement the replanning.

Our replanning estimates include the following assumptions: (1) we will de-emphasize fundamental research, broadly targeted long-range research and commercially driven research that does not support the priorities. We recognize, however, that some broad-based fundamental research must continue to be a part of our research portfolio, albeit a significantly smaller portion than before, as it invariably results in unanticipated breakthroughs that can contribute to the Vision for Space Exploration; (2) our review of the existing portfolio and plans for changes to that portfolio has begun internally, but as we progress we will seek the advice of representatives from our research community, such as through our Biological and Physical Research Advisory Council, the Institute of Medicine, and the National Research Council.

Q5b. Why does the amount of funding decline over time?

A5b. As outlined in NASA's letter to the Committee dated April 7, 2004, the Biological and Physical Research Enterprise (BPRE) is continuing to examine the Enterprise research portfolio and current plans for U.S. research on the International Space Station (ISS), with the intent to specifically emphasize research projects that most directly advance the Vision for Space Exploration.

BPRE expects to make specific decisions regarding existing and future research areas, including each of the U.S. facilities planned for the ISS, in the coming weeks. The Enterprise expects to continue to manifest many planned facilities. BPRE also expects to terminate and/or stop work on some activities, including the development and/or manifesting of selected research facilities, if it is determined that the activities do not contribute significantly to the Vision for Space Exploration, especially given the limitations on access to ISS during remaining assembly. In some cases, decisions will affect rack-level facilities, in other cases; decisions will involve multi-user "inserts" that are placed inside rack-level facilities, or experimental pieces within these inserts. In all cases, it is the intent of BPRE to provide a logical transition strategy and funding for the investigators and students who are impacted by these changes. At this time, this action is anticipated to conclude the flight hardware terminations derived from the BPRE reprioritization effort, and is expected to affect approximately three percent of planned FY 2004 BPRE funding. Following determination of relevant termination costs from these pending decisions, BPRE may propose changes in a future Operating Plan update that would redirect residual funds toward higher-priority research.

Q6. Please provide the facts and analysis used in making the decision to cancel future servicing missions to the Hubble Space Telescope.

A6. The difficult decision to not proceed with an HST servicing mission using the Space Shuttle was made after careful review of risk issues following the tragic loss of the *Columbia* Space Shuttle and crew. The safety recommendations of the *Columbia* Accident Investigation Board were used as our guide, along with our progress in meeting the recommendations in our return-to-flight activities. NASA is now challenged by safety constraints that are more difficult to address at the orbit of the HST than at the orbit of the International Space Station. They include the ability to inspect and repair the thermal protection tiles of the Space Shuttle while on orbit, the ability to provide a place of refuge for the astronauts, and the ability to have a second Space Shuttle ready to launch should a rescue mission be needed. When all factors were considered, the combined risk was deemed to high. While space flight always carries risk, reasonable precautions must be taken to protect our astronauts.

NASA is proud of the amazing accomplishments of the HST mission. The HST has met or exceeded all scientific expectations, and has provided the scientific community with a large archive of data that will continue to be maintained for many years, providing a rich source of new scientific discoveries and results. NASA is now working hard to find ways to extend the life of the space telescope for years beyond its planned minimum lifetime of 15 years, even without a Shuttle servicing mission. Furthermore, NASA is now eagerly studying and considering a robotic mission to service Hubble. Such a mission could extend Hubble's mission even beyond the end of the decade.

Q6a. What plans does NASA have for the instruments developed for the next Hubble servicing mission?

A6a. If we are indeed able to do a robotic servicing mission, then some of the components of SM–4 might still be used.

Q7. Some scientists have said that perhaps the most valuable research component of the Space Station is the Centrifuge, but it has experienced long delays and technical setbacks.

Q7a. When does NASA expect to fly the Centrifuge to the Space Station?

A7a. Delivery of the CAM to Kennedy Space Center is currently planned to support a launch to the ISS no earlier than November 2008. We are planning to fly the Centrifuge well before the Space Shuttle is retired in 2010. On July 29, 2003, NASDA President Yamanouchi confirmed Japan's commitment to provide a fully capable Centrifuge on a mutually agreed schedule that takes into account Centrifuge launch delays as a result of the *Columbia* tragedy.

Q7b. If it cannot be flown before the Space Shuttle is retired, does NASA have any backup plans to conduct the research it would have performed?

A7b. NASA has identified six alternatives to the CAM, in the event the Space Shuttle is retired prior to completion of the facility:

Proceed with animal studies on ISS at Microgravity only, as a worst case and assuming fractional gravity will be less harmful

Rely on cellular/tissue studies in smaller scale centrifuges on ISS

Increase reliance on human test subjects on ISS

Design/build NASA centrifuge for ISS

Develop and utilize free flyers

Use the Moon as a research base or develop Moon-based CAM

We are committed to studying these alternatives, although many of them may not be affordable to implement. The optimal combination in the absence of the CAM is currently under evaluation. Even with the pursuit of these alternatives, the CAM still provides unique capabilities:

Ability to simulate a full Mars mission, including (1) long duration microgravity, followed by a period of time at 3/8 gravity; (2) followed by more long duration microgravity during which we can test bone loss, immunology, and other reactions to gravity changes.

In situ dissections and detailed anatomy, physiology after exposure to fractional gravity. This information is needed to determine the mechanisms of the observed changes and guide the development of new countermeasures.

Q7c. Would it be possible to develop and fly a Centrifuge as a free flying platform to perform that research?

A7c. NASA is currently engaged in studying the free flyer option. Thus far our studies indicate that free flyers could be an early complement to ISS research using small diameter centrifuges with automated procedures for cells and small organisms to be studied at fractional gravity. However, on-orbit sampling and dissections are required to answer key questions regarding de-conditioning and adaptation effects, countermeasure efficacy and interactions. Without sampling and dissections we do not obtain insight into anatomy or biochemistry, and little physiology. Cost and time for full program will likely exceed that of the CAM.

Q8. Without the Space Shuttle after 2010, NASA will have to find other ways of delivering cargo to the Space Station as well as bring back experiments to Earth.

Q8a. What are NASA's plans for cargo delivery and cargo return after 2010?

A8a. NASA is developing an integrated ISS cargo delivery and return strategy consistent with the Vision for Space Exploration and existing law and policy. NASA is refining ISS cargo and crew rotation requirements based on the Vision and considering a full range of domestic and International Partner transportation options including:

U.S. commercial capabilities;

ISS partner assets such as the European Automated Transfer Vehicle, Japanese Transfer Vehicle, and Russian Progress and Soyuz vehicles;

Capabilities under definition in the NASA Constellation Program when available.

Q8b. How much funding has NASA assumed it will need to develop or purchase this capability?

A8b. The FY 2005 budget establishes a new line item in the ISS Program for ISS to provide for launch, delivery and return to Earth services for ISS crew and cargo.

(NOA $M)	FY05	FY06	FY07	FY08	FY09
ISS Cargo/Crew Services	$140	$160	$160	$160	$500

Q8c. When does NASA expect to make a decision on how to proceed?

A8c. There are unique challenges associated with each of these access options. NASA expects to have a preliminary strategy to discuss with Congress in June 2004.

Q9. The proposed plan calls for the Space Shuttle to retire in 2010, yet the Crew Exploration Vehicles first flight with humans on-board won't occur until 2014. Therefore, between 2010 and 2014 the U.S. will have no way to fly humans to space. During the same period, we plan to have astronauts on the Space Station and we will have to provide a means both for crew transport and crew rescue in case of an emergency.

How will crews be transported back and forth to the Space Station between 2010 and 2014? Will they have a crew rescue vehicle during this time?

A9. NASA is evaluating the manifest for all flights to the International Space Station. We are conducting the evaluation based on the Vision for Space Exploration, and on Station assembly, logistics, maintenance, and utilization requirements. We will complete the evaluation this summer. The evaluation will also include a review of available and proposed domestic and international vehicles for crew applications.

The Space Shuttle and Soyuz spacecraft are currently the only vehicles safety rated to transport crews to and from the ISS. NASA will evaluate use of the new Crew Exploration Vehicle for this purpose when it becomes available and will continue to work with the private sector and our International Partners to safely meet crew and logistics requirements.

There will always be a crew rescue vehicle docked to the ISS when the orbiting laboratory is occupied. The Soyuz spacecraft is currently the only vehicle capable and rated for crew rescue. NASA is working with our international partners to ensure adequate Soyuz spacecraft are available for safe ISS operations. The issue is being worked across the Partnership.

Q10. How many Shuttle flights are necessary to complete the Space Station?

A10. NASA currently anticipates that it will take between 25–30 Shuttle flights to complete the ISS.

Q10a. How much slack, if any, is there in the current Shuttle manifest to complete the Space Station by 2010?

Q10b. If the Shuttle manifest through 2010 is not known, on what grounds did NASA conclude that the Space Station can be completed by 2010?

A10a&b. NASA is evaluating the current manifest for flights to the ISS in light of the Vision for Space Exploration. The ISS assembly sequence and final configuration are being examined, as are the complement of currently available and proposed domestic and international vehicles that are capable of delivering crew and cargo to and from the ISS, and the predicted Shuttle return to flight date. This evaluation, which will factor in the historic turn-around time between Shuttle flights, is expected to be complete in the summer and will provide a better idea of how many Shuttle flights will be needed to complete assembly of the ISS. NASA plans to trade ISS requirements against launch capabilities to ensure that the Shuttle can be operated safely and the ISS assembly can be completed by the end of the decade, consistent with the Vision for Space Exploration.

Q11. Please explain how NASA plans to implement this portion of the new policy ("pursue commercial opportunities for providing transportation and other services supporting the Space Station and exploration mission beyond low-Earth orbit")?

A11. NASA will explore opportunities to utilize commercially developed and operated systems to the maximum extent possible to support the logistics infrastructure of the ISS and other exploration systems. Commercial systems, including launch, communications, and other end-to-end support services, will be integrated into the overall logistics planning as they are developed.

Q12. The FY 2005 budget shifts Project Prometheus, NASA's program to develop nuclear powered propulsion for spacecraft, to the newly created Exploration Enter-

prise, and it delays, by several years, the launch of the Jupiter Icy Moons Orbiter.

What is the reason for the delay?

A12. A major reason for the delay is that NASA needs some time to analyze how investments in Prometheus and the Jupiter Icy Moons Orbiter (JIMO) can be leveraged to support the Vision for Space Exploration. To meet future space exploration needs, we expect that a more detailed, wider ranging analysis, and possibly more extensive development of advanced nuclear power and propulsion systems will be required—beyond that originally envisioned when Project Prometheus and JIMO were formulated last year. Such analyses and potential future capability development includes, but may not be limited to:

Power and propulsion for advanced robotic missions after JIMO;

Potential surface power for human missions to the Moon and Mars; and

Power and propulsion for the transit of human missions to Mars or other destinations.

To aid in this analysis, NASA has asked the National Research Council to advise NASA regarding (a) scientific goals and missions that may be enabled uniquely by nuclear power and propulsion technology and (b) the engineering aspects of the missions identified.

The decision to delay JIMO was also made in light of the need to craft a credible and responsible NASA budget. Over the next few years, NASA will be returning the Space Shuttle to flight, completing assembly of the International Space Station, beginning development of a new crew transport system, and conducting vigorous space science, Earth science, education, and aeronautics programs. The previous schedule for Prometheus was unaffordable without making large cuts to these other priorities.

Q13. The President's plan calls on NASA to "pursue opportunities for international participation to support U.S. space exploration goals."

Q13a. How and when does NASA plan to engage the international community on its exploration plans?

A13a. NASA has begun informal preliminary discussions with potential partners and has heard positive reactions thus far. With the recent release of the "President's Commission on Implementation of United States Space Exploration Policy" (Aldridge Commission) provides its advice on international cooperation, NASA will move ahead with pursuing international cooperation.

Q13b. Will NASA develop the plan and then invite international partners to participate, as was done on the International Space Station, or does NASA plan to involve the international partners in the formulation of the project?

A13b. We expect there will be a mix of approaches based on the specific needs of individual programs. In many exploration missions that focus on science, there is already substantial international cooperation which begins in the early stages of a program.

Q13c. China launched its first astronaut last year. Will NASA seek participation from China or allow China to participate?

A13c. No country, including China, has been excluded from participation at this stage. If Chinese participation advances the goals of the vision and is consistent with broader U.S. policy objectives, NASA will consider it at the appropriate time.

Q14. Does NASA plan to use existing launch systems, such as the Atlas 5 and Delta 4, to implement any aspect of the President's initiative for human space flight or will it require the development of a larger "heavy-lift" system?

A14. NASA is developing architectures and requirements necessary to implement the Vision for Space Exploration. NASA plans to continue to utilize a Mixed Fleet Launch Strategy to meet space launch requirements, relying on both domestic and international launch capabilities. As part of the ongoing internal trade studies, capabilities of existing systems, such as the Atlas V, Delta IV, and partner systems, are being considered, as well as contractor-proposed vehicle enhancements to performance and reliability. Ideas for meeting the to-be-defined space transportation requirements are also being offered by emerging domestic companies.

Q14a. If the answer has not yet been determined, when does NASA expect to have the information to make that decision?

A14a. NASA expects to have initial human space flight exploration requirements and a flexible architecture defined within the next 12 to 18 months. Over the next 12 months, NASA will develop a roadmap that identifies when key decisions need to be made on investments, including any future launch enhancements/developments, which will be included in future updates to the NASA Integrated Space Transportation Plan.

Q14b. Do NASA's five- and 20-year budget projections assume it will be able to use existing vehicles or do they include the development of a new heavy-lift launch vehicle?

A14b. The President's proposed budget for NASA was designed to be sufficient to allow the execution of the Vision for Space Exploration, whether or not a new heavy lift launch vehicle is required. NASA is currently defining detailed program requirements, which will determine the necessity of such things as a new heavy lift vehicle. This information will be used as part of the FY06 budget planning process.

Q15. Does NASA expect to have anything other than full and open competitions for any contracts involving the Crew Exploration Vehicle? If not please explain.

A15. NASA plans only full and open competitions for the CEV, starting with Broad Area Announcements (BAA) in June 2004 and an RFP in January 2005. NASA plans to maintain competition through flight demonstrations in 2008.

Q16. In response to questions from Congressman Bart Gordon, NASA said that a decision about the U.S. government's role in the Space Station will not be made until the middle of the next decade. However, NASA's budget projections through 2020 show that it no longer plans to support the Space Station after 2016.

Why does NASA's budget projection make an assumption that NASA as a whole appears unable to make?

A16. The 2016 budget projection for the Space Station was based on a fifteen-year operating life after the deployment of the U.S. Laboratory and predates the Vision for Space Exploration. The ISS end of service life was documented in the Cost Analysis Requirements Description (CARD) approved in May 2002, and will be updated as requirements for on-orbit research evolve over the life of the program. This is consistent with the response provided to Congressman Gordon.

Q17. Are Return-To-Flight (RTF) activities budgeted and managed as a separate line within the Space Shuttle account?

A17. Although Return-to-Flight (RTF) activities are not budgeted as a separate line item, NASA does manage these funds separately. RTF activities are approved for implementation by the Space Flight Leadership Council and managed by the Space Shuttle Program Requirements Control Board (PRCB).

Q17a. If not, what are the criteria for determining which activities should be included in the breakdown of cost estimates provided to the Committee for RTF?

A17a. NASA bases the RTF estimates provided to the Committee on the corrective actions necessary to address the CAIB recommendations, as well as other "raising the bar" initiatives, after they have been reviewed and approved by the PRCB.

Q17b. NASA produced the initial RTF cost estimate on October 10, 2003, and provided revised estimates to the Committee on November 17, 2003, and January 30, 2004. Please explain the reason for the increased estimates for these costs, including details about the assumptions and the technical content that have changed. What is the basis of estimate for these costs?

A17b. The costs to address RTF activities have increased as new tasks have been approved, the scope of work for previously approved tasks has increased, and/or cost estimates have been refined. Although there is a greater level of technical maturity for RTF activities, engineering requirements are still evolving. Cost estimates therefore remain dynamic, and are still under evaluation. As appropriate and depending on data available, estimates are based on cost relationships derived from previous cost histories, cost analogues for similar work, or engineering estimates for components of unique activities, including studies, design efforts, development, production, integration, certification, verification, implementation and retrofit.

Q17c. Please provide the five-year runout for RTF activities included in the FY05 budget.

Q17d. Please provide a breakdown of the current estimate for RTF costs, if different than the FY05 budget levels.

A17c&d.

Shuttle - Return to Flight

As of 01/30/2004

				FY 2005 - FY 2009 Under Review					
		FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	Total
	Initiated RTF Activities	**92**	**264**	**238**	**177**	**166**	**67**	**76**	**1079**
RE/AC	Orbiter RCC Inspections & Orbiter RCC-2 Shipsets Spares	4	21	30	30	30			115
RE	On-orbit TPS Inspection & EVA Tile Repair	46	53	48	30	13			190
RE	Orbiter TPS Hardening	4	17	47	45	46			160
	Orbiter Certification / Verification	2	3						5
RE	External Tank Items (Camera, Bipod Ramp, etc.)	26	60	45	30	30	30	30	251
RE	SRB Items (Bolt Catcher, ETA Ring Invest., Camera)	0	14	13	7	4	1	1	40
RP	Ground Camera Ascent Imagery Upgrade	8	36						44
RE/AC	Other (System Intgr. JBOSC Sys, SSME Tech Assess, Ground Ops Workforce)	2	60	55	35	43	36	45	275
RE	**Stafford - Covey Team**	**2**	**1**						**3**
	Total SSP RTF Activities	**94**	**265**	**238**	**177**	**166**	**67**	**76**	**1082**
	***Other RTF Related**								
	NASA Engineering and Safety Center (NESC)		**45**	**77**	**93**	**95**	**96**	**97**	**503**

RE = Reestimated Item (on 11/19/03 list); AC = Added Content, RP= Repahsed Funding Profile

*NASA Engineering and Safety Center (NESC) is funded through NASA's Corporate G&A. The NESC at the agency's Langley Research Center in Hampton, Va., and provides comprehensive examination of all NASA programs and projects.

Q17e. What affect does the recent schedule slip for RTF to March 2005 have on RTF costs?

A17e. NASA is reassessing the RTF technical, schedule, and cost requirements as part of the FY 2006 budget formulation process. Revised cost estimates will be shown in the periodic releases of the NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond, or through separate correspondence if significant changes are realized prior to a scheduled RTF plan update.

Q18. NASA's briefing materials include funding for the NASA Engineering and Safety Center (NESC) along with its RTF cost estimates, however, NESC is paid for through General and Administrative (G&A) accounts.

Why is NESC funding displayed as part of RTF costs?

A18. NASA has displayed costs associated with the NESC separately from RTF costs, and identified as "Other RTF Related." Please note that funding for NESC is not included in the totalization of RTF costs because the NESC provides comprehensive engineering and safety assessment of all NASA programs and projects, including the Shuttle. In fact, only a portion of the NESC costs in the first six months of its existence have been applied to the assessment of Shuttle technical problems. However, it is fully anticipated that a significant percentage of NESC expenditures in the first several years will be devoted to Shuttle technical problem assessment. Consequently, NASA elected to display costs associated with the NESC separately from total RTF costs for information and to acknowledge other sizable investment efforts that are direct outcomes of the *Columbia* tragedy.

Q19. Does NASA's budget projection through 2009 assume maintenance and operation of NASA's current level of infrastructure?

A19. No. NASA's budget projections for infrastructure repair, maintenance and operation are based on our known infrastructure needs at the time of the projections. Many facilities have been or are planned to be mothballed or put on "standby." In addition, NASA has allocated $10 million per year for FY04 through FY 2007 for facilities demolition to remove older, excess facilities from our infrastructure base. And we are also planning to lease out under-utilized facilities to the extent possible, especially through our recent Enhanced Use Leasing demonstration authority. We are also implementing an innovative Reliability Centered Maintenance concept at our Centers to increase facility maintenance efficiency. All those actions help to reduce infrastructure costs, however, NASA's infrastructure continues to age, and maintenance and repair costs for remaining infrastructure continue to rise. NASA is committed to ensuring that our facilities are of the right type and size, are safe, secure, and environmentally sound, are quality workplaces, and are affordable.

Q19a. Does NASA have any plans to review its infrastructure?

A19a. Yes, NASA has plans to review its infrastructure.

Q19b. If so, what is the schedule for such a review?

A19b. There is a two-fold process in place: First, NASA reviews its infrastructure yearly during budget preparations. The need for existing facilities, as well as the condition of those facilities, is analyzed as part of the budget process. Second, NASA is conducting a Real Property Mission Analysis (RPMA) which is reviewing all NASA real property with an independent, mission-driven, top-down process to develop the proper balance of real property as it supports NASA's vision and mission. The RPMA team was formed in February 2004 and has been conducting data gathering and site visits. The RPMA is expected to conclude no earlier than December 2004. Implementation of approved recommendations will depend on the scope of those recommendations.

Q20. The current Progress vehicle manifest indicates that only three flights are planned this year rather than the four previously agreed to by the Multilateral Coordination Board (MCB). What is the rationale for this change?

What effect would a Progress mission failure have on the Space Station program?

A20. Within a month of the Space Shuttle *Columbia* accident, the ISS Multilateral Coordination Board (MCB) approved a near-term ISS operations plan that would allow the Partnership to maintain a continued crew presence on the ISS until the Space Shuttle is able to return to flight. Among other things, the plan approved as a goal that the Russian Progress flight schedule be accelerated to support crew and ISS consumable needs until the Space Shuttle returns to flight. Since late February

2003, the near-term operations plan has been continuously reviewed and updated as required. Modifying this operations plan to reflect improved conditions is a normal part of ISS operations and does not require MCB approval.

The key constraint driving the near-term ISS operations plan has been projected consumable usage with water being the limiting item. However, actual water usage has been less than predicted. The NASA and Russian program management staffs have on-going technical discussions to determine a revised Progress schedule based on actual experience to date with on-orbit consumables. Consumables are managed so that the loss of a Progress resupply mission would not require immediate de-crewing of the Station. Procedures exist for orderly de-crewing of the ISS should this be required. The need to implement this response will be dictated by the state of consumables aboard the ISS. Efforts to accelerate the next supply vehicle launch would probably be conducted in parallel with preparation for de-crewing if a Progress mission failure were to occur and consumables were critical.

Q21. One of the fundamental questions in space policy is how much risk we should ask astronauts to assume. The Shuttle is being discontinued because of its risks; the Hubble mission was canceled because of its risks. How will the risks of a lunar landing compare with those of current activities?

A21. Project Apollo made six successful lunar landings in six attempts (Apollo XIII did not attempt a lunar landing) between 1969 and 1972. That record was made with 1960s technology. It is NASA's expectation that, with 21st century technology and the experience gained in all aspects of space activity since the time of Apollo, the risk of lunar landing will be significantly less than it was in the 1960s/1970s. Our Level 1 requirements for the development of lunar systems should reflect this expectation. All the trade studies being done to develop the lunar mission requirements are specifically determining which system hazards to the crew and vehicle are associated with each part of the mission and how those hazards can be mitigated through vehicle design and technology advancements.

Q21a. How about the risks of longer-term activities on the Moon, or a landing on Mars?

A21a. A Mars mission should pose a similar risk to the crew as a long ISS mission combined with a lunar exploration mission, with the exception that there will be no quick abort-back-to-Earth capability that one has with ISS and lunar missions. As a result, there will be added emphasis on flight system safety and reliability and on-board medical care to handle crew injury/illness risks. NASA's Exploration Systems Enterprise is conducting trade studies to determine the optimum system configuration for both the lunar surface missions and the Mars missions. Integral to these trade studies is an assessment of the extent to which the architecture will ensure safety for all mission phases. This includes identifying mission and *crew health risks* and system hazards, abort options for all mission phases, and system design redundancy and reliability.

Q21b. What risks will astronauts be asked to assume as participants in the new biological experiments that are planned for the Space Station?

A21b. Space Station crew members will be asked to assume minimal or reasonable risk as participants in biomedical/biological experiments. The definition of *Minimal Risk* is "the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests" (from *45 CFR 46.102(i)*). The definition of *Reasonable Risk* is "the probability and magnitude of harm or discomfort anticipated in the research are greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests, but the risks of harm or discomfort are considered acceptable when weighed against the anticipated benefits and the importance of the knowledge to be gained from the research" (from *JSC 20483*). Minimal risk and reasonable risk judgments for clinical research have been used for many years. These applications, which are utilized by our Institutional Review Board process (now Committee for the Protection of Human Subjects), have also been in place for many years. A consistent process has and will be applied to ISS.

The astronauts will be volunteers who will be fully informed regarding (1) the nature of the research to be performed on them, and (2) the probable risks. Most of the studies performed will be in the "Minimal Risk" category. A few studies will be in the "Reasonable Risk" category. It is important to note that the research will benefit the astronaut research subject directly by either acting as a countermeasure or by better defining the risk to human health resulting from space flight.

Q21c. What is NASA's overall philosophy as to what constitutes acceptable risk?

A21c. There are four major categories of risk that NASA is faced with: (I) safety and health risk to the public, (II) safety and health occupational risk (risk to astronauts and other NASA and contractor workforce), (III) risk to high-value property, and (IV) programmatic risk.

In NASA Procedural Requirements (NPR) 7120.5B, NASA Program and Project Management Processes and Requirements, November 21, 2002, *risk* is defined as follows:

Risk. The combination of (1) the probability (qualitative or quantitative) that a program or project will experience an undesired event such as cost overrun, schedule slippage, safety mishap, compromise of security, or failure to achieve a needed technological breakthrough; and (2) the consequences, impact, or severity of the undesired event were it to occur.

Acceptable risk is defined in the same document as follows:

Acceptable Risk. The risk that is understood and agreed to by the program/project, GPMC [Governing Program Management Council], Enterprise, and other customer(s) sufficient to achieve the defined success criteria within the approved level of resources.

This is how NASA defines *acceptable risk* in a programmatic context. It is this definition of *acceptable risk* that would ultimately apply to the development of new Exploration systems. More specific (quantitative) requirements for *acceptable risk* will be found in the requirements documents for specific flight systems, such as the Crew Exploration Vehicle (CEV). These requirements will affect the risk to crew members, as well as the risk to people and property external to the flight systems.

In situations where the public or other external stakeholders are involved or affected, it is NASA's policy to augment the concept of acceptable risk to include risk that is acceptable to the broader group(s) of affected stakeholders. In many of these cases, ensuring that risk is maintained below threshold levels of acceptability dictated by compliance with federal, state, local, or other specific types of requirements may satisfy risk acceptability for these affected groups. From a safety standpoint, NASA will ensure that the risk to the general public and foreign countries will be no greater than that for conventional aircraft flying overhead, as referenced in Legislative History, 81st Congress, p. 1235.

Q22. What milestones for assessment are built into the major aspects of the exploration initiative? At what point should NASA and the Congress re-examine the initiative, particularly CEV development, to determine whether it is appropriate to proceed to completion?

A22. The acquisition plan for the CEV and other elements of Project Constellation builds in decision milestones as follows:

Milestone A initiates the technology maturation and concept design phase of the program.

Milestone B initiates development after successful completion of the System Requirements Review and a System Design Review.

Milestone C initiates final design certification.

This milestone process will occur in a phased approach to all Project Constellation elements, starting with the Crew Exploration Vehicle (CEV). NASA intends to utilize an evolutionary acquisition approach that approves entrance to the next step of development when requirements for that phase (entrance criteria) are fully developed.

Q23. How likely is it that we will know enough about the effects of radiation and lack of gravity by 2016, when NASA apparently plans to stop using the Space Station?

A23. The ISS has a number of U.S. and Russian devices, both active and passive, for monitoring radiation on the Station. In addition to the on-board monitoring capability, we rely on real-time monitoring and forecasting data from the NOAA Space Environment Center. These data provide an early warning for proton fluxes and other radiation events, and allows us to take steps to mitigate crew exposure. In this way, we continue to build our essential data record on space radiation.

Q23a. How would research be conducted after that point?

A23a. We will continue to perform a range of experiments on Earth in conjunction with the measurements that monitor the radiation aboard the ISS. To ensure the

safety of spacecraft crews, NASA biologists and physicists will perform thousands of experiments at the new NASA Space Radiation Laboratory (NSRL) commissioned at the Department of Energy's (DOE) Brookhaven National Laboratory in Upton, N.Y. This laboratory, built in cooperation between NASA and DOE, is one of the few facilities that can simulate the harsh space radiation environment. With approximately 80 investigators conducting research annually, the NSRL will enable us to triple the ability of researchers to perform radiobiology experiments and the resulting science knowledge in the coming years and beyond our use of the ISS.

Questions submitted by Representative Bart Gordon

Q1. What did the President ask you about the costs of the President's space initiative, and how did you respond?

A1. The exploration vision is affordable in both the short-term and the long run. NASA's FY 2005 budget request is fiscally responsible and consistent with the Administration's goal of reducing the budget deficit by over 50 percent within the next five years. The budget strategy supporting the exploration vision places a premium on avoiding balloon payments for future Congresses and Administrations. Unlike previous major civil space initiatives, the approach is intentionally flexible, with adjustable exploration milestones and investments in sustainable exploration approaches to maintain affordability.

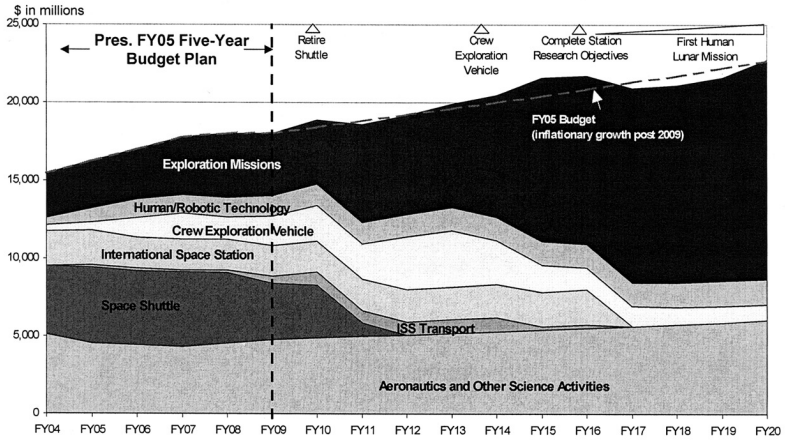
Q2. How much do you estimate it will cost to achieve a human lunar landing by 2020, and what assumptions are included in that estimate?

A2. NASA has developed a budget projection through 2020 to define the resources that will be available to achieve the vision for space exploration, as shown in table below [sand chart]. The first five years are based on the details contained in the President's FY 2005 Budget request, and fiscal years 2010–2020 are based on roughly inflationary growth. NASA has taken the unusual step of projecting the budget beyond five years to demonstrate the exploration vision's sustained and affordable approach, which redirects resources within NASA and does not require balloon payments beyond the normal five-year budget horizon.

The President's five-year FY 2005–2009 budget request establishes necessary groundwork for the execution of the exploration vision. Proposed near-term investments are focused on technology risk reduction and flight experiments as well as robotic missions throughout solar system.

The table below shows a rough estimate for the cost of the exploration initiative through 2020 including the initial human lunar landing sometime between 2015 and 2020. Projections for the blue "Exploration Missions" wedge over the period FY 2010–2020 total approximately $103 billion and include both human and robotic exploration activities. Human lunar activities over this time period including the initial landing and subsequent activities represent about half of this total. This represents a bounding estimate based on experience and actual costs from relevant elements of the Apollo program. The estimate does not reflect architecture studies, design analysis, new technologies, and innovative approaches yet to be undertaken. It also does not reflect that the vision, unlike Apollo, views the lunar landing not as an end in itself, but as one step in a sustained human and robotic program to explore the solar system and beyond.

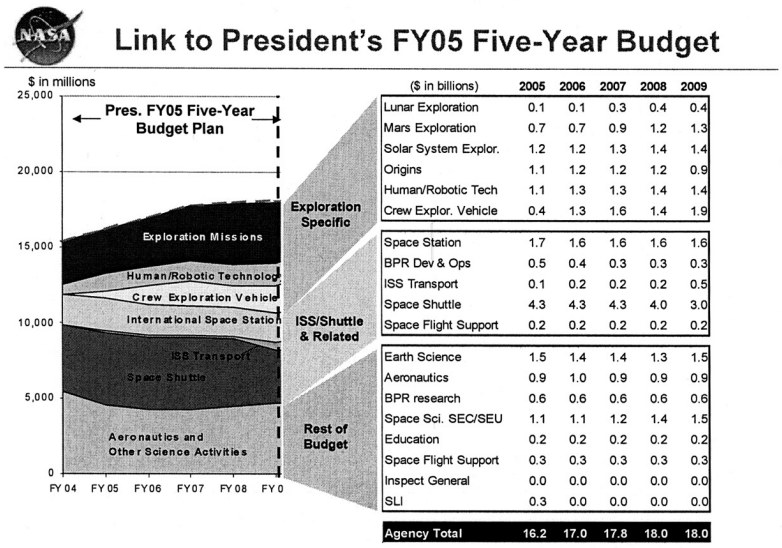
Strategy Based on Long-Term Affordability



NOTE: Exploration missions – Robotic and eventual human missions to Moon, Mars, and beyond
Human/Robotic Technology – Technologies to enable development of exploration space systems
Crew Exploration Vehicle – Transportation vehicle for human explorers
ISS Transport – US and foreign launch systems to support Space Station needs especially after Shuttle retirement

Q3. As was agreed at the hearing, please provide a breakdown of what programs are included in each of the wedges of the "sand chart" displayed at the hearing.

A3.



($ in billions)	2005	2006	2007	2008	2009
Lunar Exploration	0.1	0.1	0.3	0.4	0.4
Mars Exploration	0.7	0.7	0.9	1.2	1.3
Solar System Explor.	1.2	1.2	1.3	1.4	1.4
Origins	1.1	1.2	1.2	1.2	0.9
Human/Robotic Tech	1.1	1.3	1.3	1.4	1.4
Crew Explor. Vehicle	0.4	1.3	1.6	1.4	1.9
Space Station	1.7	1.6	1.6	1.6	1.6
BPR Dev & Ops	0.5	0.4	0.3	0.3	0.3
ISS Transport	0.1	0.2	0.2	0.2	0.5
Space Shuttle	4.3	4.3	4.3	4.0	3.0
Space Flight Support	0.2	0.2	0.2	0.2	0.2
Earth Science	1.5	1.4	1.4	1.3	1.5
Aeronautics	0.9	1.0	0.9	0.9	0.9
BPR research	0.6	0.6	0.6	0.6	0.6
Space Sci. SEC/SEU	1.1	1.1	1.2	1.4	1.5
Education	0.2	0.2	0.2	0.2	0.2
Space Flight Support	0.3	0.3	0.3	0.3	0.3
Inspect General	0.0	0.0	0.0	0.0	0.0
SLI	0.3	0.0	0.0	0.0	0.0
Agency Total	**16.2**	**17.0**	**17.8**	**18.0**	**18.0**

Q4. As was agreed at the hearing, please provide the total funding included within the blue "Exploration Missions" wedge over the period FY 2010–2020. Is it accurate, as you seemed to say at the hearing, that the funding within this wedge does equate with the funding necessary to achieve the President's lunar objectives, including human missions to the Moon by 2020. If that is true, what components of these lunar objectives (e.g., a lunar lander) are not encompassed within the blue wedge?

A4. Projections for the blue "Exploration Missions" wedge over the period FY 2010–2020 total approximately $103 billion and include both human and robotic exploration of the Moon and robotic exploration of Mars, other solar system destinations, and beyond. As stated in the response to Question 2 above, this level of funding represents a bounding estimate based on experience and actual costs from relevant elements of the Apollo program. The estimate does not reflect architecture studies, design analysis, new technologies, and innovative approaches yet to be undertaken. It also does not reflect that the vision, unlike Apollo, views the lunar landing not as an end in itself, but as one step in a sustained human and robotic program to explore the solar system and beyond.

Q5. If certain of the programs in the President's initiative wind up costing more than you expect, will you ask for more money, propose additional cuts to other activities, or stretch out the timeline?

A5. NASA intends to pursue the President's Vision for Space Exploration within the funding projections in the FY 2005 budget request. As we learn more and refine our cost estimates, the scope of our planned activities and schedule may be adjusted to be consistent with funding projections, while still meeting the vision put forth by the President.

Q6. In response to a written question asking whether the Administration plans to transfer any current NASA activities or programs to other agencies or the private sector over the next five years, you did not deny that possibility. Instead you stated, "Some programmatic decisions are still under consideration and will be announced at the appropriate time."

Q6a. What specific "programmatic decisions" are under consideration?

Q6b. What activities or programs are being considered for transfer to other agencies or to the private sector?

A6a&b. There are no programs currently identified for transfer to other agencies or to the private sector. NASA will review the recently released report of the President's Commission on Implementation of United States Space Exploration Policy with respect to such possible considerations.

Q7. One of the significant policy decisions embedded in the President's plan is the decision to terminate the Shuttle program years before a replacement vehicle will be available. Basically, that means we will be dependent on the Russians for getting our astronauts into space. Leaving aside the question of the Iran Nonproliferation Act, why does it make sense to rely on Russia to provide access to space for American astronauts for a number of years?

A7. Development of a new U.S. crewed space system will cost billions of dollars. Until the Shuttle—which costs over $4 billion per year to operate—is retired, funding available within NASA's budget for developing the new crew exploration vehicle (CEV) is limited. Speeding up the schedule for CEV availability would either require large increases to NASA's budget, or drastic cuts to other NASA programs. Extending the operational life of the Shuttle also does not solve the problem—each year the Shuttle continues operating past 2010 is another year that billions of dollars are not available for CEV development, resulting in delays to CEV availability. For these reasons, we believe that the only affordable approach to transitioning between the Shuttle and CEV is to rely on others to launch U.S. astronauts during the period between Shuttle retirement and CEV availability.

The ISS Program is currently reviewing plans for assembly completion and operations as part of the FY 2006 budget formulation activity. Crew transport to/from the ISS after Shuttle retirement is a consideration in this effort. Discussions with our international partners concerning how to best proceed with ISS operations in light of the decision to retire the Shuttle will be held in summer 2004. If the decision is made to use Russian crew transport services, we will be working with a reliable partner. In the wake of the *Columbia* accident, Russia has provided, consistent with partnership agreements, Soyuz flights to transport crews and Progress vehicles to ferry supplies to the ISS during the current hiatus in Shuttle flights.

Q8. The February 7, 2004 edition of the New York Times *reported that the NASA engineer who had written a pair of internal assessments of the risk of the Hubble servicing mission that were at odds with your justification for canceling the mission "declined to be identified for fear of losing his job." That is a very troubling indication that the NASA culture, as described by the* Columbia *Accident Investigation Board as one that discouraged dissent, still exists. What specific steps have you taken to ensure that the employee will face no reprisals for his/her actions, and what assurance have you given that employee—and all NASA employees and contractors—that you consider such dissent healthy and welcome?*

A8.

Background

NASA had begun to address issues of "culture" before the *Columbia* accident. Even as the 2002 Federal Human Capital Survey results identified NASA as one of the best places to work in the Federal Government, a grassroots effort was underway to explore issues within the NASA culture that, if addressed, could improve the Agency's effectiveness and performance.

In July 2002, a team of NASA and contractor employees began working to assess the feasibility and define the action plan needed to create a more highly unified NASA organization. This One NASA team set out to formulate a set of specific recommendations for organizational and cultural change, emphasizing teamwork and collaboration across the Agency, which would elevate NASA to a new level of effectiveness and performance.

The CAIB issued its report in August 2003, a mere seven months after the tragic loss of *Columbia* and her crew, and found that NASA's history and culture contributed as much to the *Columbia* accident as any technical failure. This is explicitly identified in the Organizational Cause Statement found in Chapter 7 of the report. This chapter gave us a very candid look into our organizational culture and provided us with a great opportunity to take a deeper look at our culture, to look at those aspects that are positive and also those that need improvement, and to take action to achieve positive, long-lasting change at NASA.

Progress and Actions

Safety Climate and Culture Survey

Based upon the CAIB report and our desire to place even greater attention on moving to a more effective culture, we felt it would be beneficial to engage external expertise to assist us in developing and deploying an organization plan for culture change at NASA. To this end, on February 9, 2004, NASA awarded a contract to Behavioral Science Technology, Inc. (BST), an organization with specific expertise and proven track record helping organizations achieve safety excellence through culture transformation and leadership development.

The first part of BST's effort involved establishing a baseline of our culture by administering a Safety Climate and Culture Survey. BST delivered the final survey results, along with a recommended implementation plan for NASA to achieve positive improvements in its culture, in a report entitled, *Assessment and Plan for Organizational Culture Change at NASA,* which is available on the NASA HQ website *(http://www.nasa.gov/about/highlights/index.html).*

The results of the survey support NASA's legacy of technical excellence, teamwork, and pride, indicating that we are strong in areas such as teamwork, work group relations, approaching coworkers about safety concerns, and reporting incidents or deviations that affect safety. The survey also identifies important safety and organizational issues that must be addressed before we can initiate positive changes within the agency. There is a general perception that the organization as a whole does not show concern for the needs of employees. There is also a perception that there are deficiencies in the quality and quantity of upward communication about safety issues.

While these issues are similar to those highlighted in the *Columbia* Accident Investigation Board Report, this *Assessment and Plan for Organizational Culture Change at NASA* has given us specific data to assess organizational functioning down to the directorate level, as well as a specific plan of action for improving these aspects of our culture.

Implementation Plan

One of the first steps of this plan will be for the core leadership team to validate and embrace NASA's Core Values. These values will drive the culture change effort. The plan also calls for focused change-related activities to take place at a specific Centers and Directorates, with the aim of achieving measurable results in five months.

These activities will first take place at Glenn Research Center, the Engineering and Mission Operations Directorates at Johnson Space Center, the Safety and Mission Assurance Directorates at Goddard Space Flight Center and Kennedy Space Center, and at Stennis Space Center. Activities at these locations will include leadership practices assessments, development of individual action plans for Center leadership, behavioral observation and feedback, and behavior-based project team effectiveness training.

Additionally, in the next months, BST will assist each Center in developing Center-specific implementation plans to achieve positive cultural improvements, driven from NASA's core values, while accommodating the unique needs of each Center.

At the end of five months, we will use specific data and feedback to determine if measurable progress has been achieved, including whether NASA leadership has adopted behaviors that support the desired culture. Once measurable progress has been achieved and the processes used to achieve forward progress have been validated, NASA plans an agency-wide deployment of the above-mentioned approach.

In addition to specific implementation steps we can undertake to achieve positive change in our culture, the plan also emphasizes the need for a single culture change initiative that integrates existing activities where appropriate but minimizes the proliferation of multiple approaches, philosophies, models, methods, and terminology. This culture change effort that NASA is undertaking will serve as an integration point to ensure that all the Agency's ongoing efforts related to culture change are aligned in a manner conducive to a comprehensive organizational culture change.

Culture Change Efforts and NASA OmBuds Program

A very important aspect of this culture change effort is to create an environment in which it is routine to actively solicit the minority opinion, enabling employees to feel comfortable raising safety concerns to their supervisors and Center and Agency management. In part, this will be achieved through focusing on helping managers and supervisors maintain an effective balance between task orientation and relationship orientation. The survey results and assessment indicate that at NASA, many managers have a natural inclination toward task orientation, which is not un-

usual for technical organizations. However, strong task orientation at the expense of relationship orientation can lead to inhibition of upward communication. By taking steps to help managers and supervisors improve their balance between task and relationship orientation, NASA can move toward a culture where people really feel free to speak up without retribution.

In addition to the culture change effort, on January 27, 2004, the NASA Administrator announced the establishment of NASA's Ombuds Program, empowering Ombuds at each NASA Center and Headquarters to listen to and act on employees' concerns related to safety, organizational performance and mission success. The Ombuds are designed to serve as a safety valve when employees feel regular channels for raising issues and concerns are not working effectively. Each Ombuds has the ability to raise issues directly with Center Directors, and at Headquarters with the Deputy Administrator. The Assistant Administrator for Institutional and Corporate Management leads the program, and names of the designated Center Ombuds were provided to the NASA workforce.

Question submitted by Representative Todd Akin

Q1. As you well know there has been a significant public outcry to save the space telescope from the general public, but I have also heard that some in the scientific community are very concerned about the impact to real scientific research capability that the loss of the Hubble Space Telescope (HST) may cause. Even though ground based telescope technology continues to advance, notably in adaptive optics to help combat the blurring effects of the Earth's atmosphere on astronomical observations, the HST still provides far greater resolution over greater fields of view than any ground telescope. The HST also provides tremendous ultraviolet capability that does not exist with Earth based scopes. Many astronomers consider the HST's Ultra-Violet (UV) capability very valuable. For example, I am told that UV light typically radiates from extremely hot, dynamic phenomena, such as the cores of active galaxies, quasars, energetic stars and vast disks of dust around black holes. Given the superior resolution and unique UV capabilities of the HST do we not risk the loss of a significant research capability with the retirement of the HST? Are there any alternatives to recapture this UV capability when HST ceases to function?

A1. The Hubble Space Telescope has made tremendous contributions to astronomical discovery, and it continues to produce world-class scientific results. Hubble was designed for a nominal mission length of at least 15 years, a milestone that will be reached in 2005. Within this span, Hubble has reached or exceeded every one if its scientific and technical goals and expectations. NASA plans to extend Hubble's mission for several more years by judicious use of the telescope's battery power and pointing capability, and possibly by a robotic servicing mission, which is currently under study. As a result of extensive planning and advice from the astronomical community, NASA also has over 30 newer space astronomy and physics missions in operation or in development; these will continue to support a vigorous national and international astronomical research program. Hubble is the first of NASA's four "Great Observatories," Hubble has capabilities at visible, infrared, and ultraviolet wavelengths.

The other three Great Observatories include the Chandra X–Ray Telescope, the Compton Gamma-Ray Observatory, and the infrared Spitzer Space Telescope. Compton's mission is completed, and Chandra and Spitzer are in the prime phase of their missions, producing astounding results.

Energetic phenomena such as active galaxies, energetic stars, and material around black holes are often best observe at X–Ray wavelengths, studied with Chandra and other telescopes like XMM–Newton. Many other space telescopes with various wavelength capabilities are also planned or in operation. In visible light wavelengths, Hubble still provides the best resolution and sensitivity available for many types of observations. However, in recent years, large ground-based observatories (such as the Keck telescopes) have developed remarkable capabilities for precision observations in visible and infrared light, employing larger telescope apertures and innovative techniques. For example, at infrared wavelengths, the use of Adaptive Optics on ground-based telescopes can now achieve a precision comparable to that of Hubble. For studies at ultraviolet (UV) wavelengths, a space-based capability is required. It is likely that the ultraviolet capability of Hubble will be maintained even longer than that of some other wavelengths such as infrared, due to the lower power consumption required. Two other NASA missions in addition to Hubble are also currently available for observations at ultraviolet wavelengths: GALEX and

FUSE. FUSE performs precision spectroscopic studies, and GALEX allows ultraviolet imaging over fields of view larger than that seen by Hubble.

Future large astronomy missions (including wavelength coverage of those missions) are planned in concert with prioritization efforts of the scientific community, such as the Decadal Surveys of the National Research Council. For example, the highest priority for large space-based astronomy missions in the latest decadal survey is for the highly sensitive observations at infrared wavelengths that will be achieved by NASA's James Webb Space Telescope, due to launch in 2011. Future moderate-size missions for ultraviolet and other wavelength observations can be realized through NASA's highly successful and competitive Explorer program. NASA is also currently soliciting and receiving ideas from the community for larger missions at any wavelength range.

NASA's regular strategic planning process gets underway this year, and through this process the proposals and expertise of the scientific community are employed to help set priorities for future NASA astronomy missions.

Questions submitted by Representative Nick Lampson

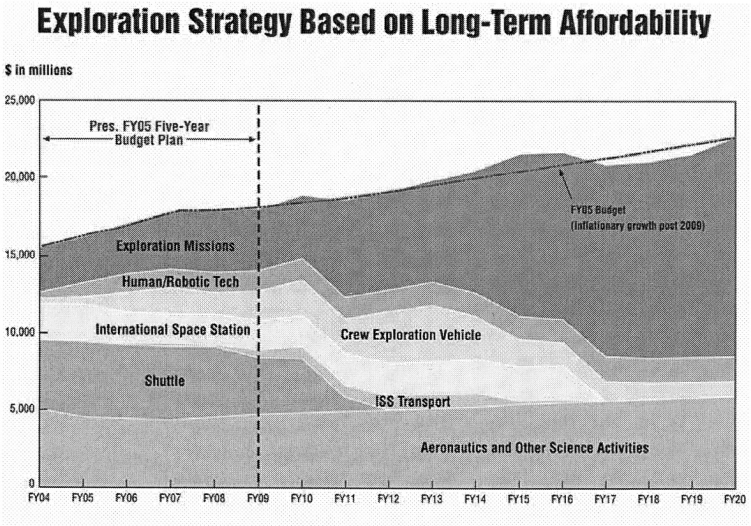
Q1. In order to free up money for the President's initiative, the budget plan would basically lump Earth Science, Aeronautics, Education, some parts of Space Science, and some parts of Biological and Physical Research together in an account whose purchasing power, according to one of the charts describing the President's initiative, will decline by some 40 percent over the next fifteen years. That means that any increase in any one of those program areas will necessitate cuts to one or more of the other areas—while the total pot of real dollars continues to decline.

Q1a. Is the plan to slowly starve those other programs for resources until NASA can terminate its involvement in them?

Q1b. If not, what is the rationale for that funding approach?

A1a&b. NASA is not changing its fundamental account structure in the manner suggested by the question. The proposed Exploration, Science and Aeronautics account contains the same key research elements as todays Science, Aeronautics and Exploration account: Space Science, Earth Science, Biological and Physical Science, Aeronautics and Education. Further, this account is not separate from the vision—rather, some of these elements are critical to the new vision.

NASA is committed to its full mission and will continue to invest in all of these important areas. The chart below shows the prospective budget for NASA beyond our five-year horizon. This figure, which has been widely distributed, illustrates NASA's public plan to conduct the vision in both the short-term and the long-term without large NASA budget increases. In this chart, the activities described in the question do not decline, but rather are shown as increasing at an inflationary level beyond the five-year budget horizon, maintaining their relative purchasing power within the entire NASA budget.



Q2. In order to fund the Presidents initiative, cuts, deferrals, and cancellations will be made to a wide range of NASA programs.

Q2a. Did you offer to make such cuts in order to fund the Presidents initiative, or were you directed to make such cuts? If the latter, who directed you to make them?

A2a. The NASA budget process evaluated and selected programs with respect to four key principles:

Compelling—The programs fully support the Vision for U.S. Space Exploration or provide for ongoing NASA mission priorities such as Aeronautics and Earth Science in accordance with the NASA Strategic Plan.

Affordable—The programs are part of a budget that is fiscally responsible and consistent with the Administration's goal of cutting the federal deficit in half within the next five years.

Achievable—The programs will not require large balloon payments by future Congresses and Administrations.

Focused—The exploration vision provides the needed compass with which to evaluate our programs and make the required tough decisions.

Q2b. Why are the science and aeronautics programs that have been cut, deferred, or canceled considered a lower priority than the President's Initiative?

A2b. The Vision for Space Exploration challenges NASA to implement a sustained and affordable human and robotic program for the exploration of the solar system and beyond. This challenge also requires changes in the research agenda of the International Space Station to intensify the emphasis on understanding how space environments affect astronaut health and capabilities as well as the development of effective countermeasures. We recognize the importance of basic research that can uniquely be pursued on the ISS as a part of our research portfolio, as it both informs applied mission-driven research and invariably results in unanticipated breakthroughs that can contribute to the exploration agenda. We plan to emphasize research on the ISS that will support the Nation's new exploration agenda. Life science research conducted by NASA will not only benefit future manned space missions, but will also lead to the improvement of life here on Earth, including applications in medicine, agriculture, industrial biotechnology, and environmental management.

Earth science research remains a priority for NASA. Although some new projects were postponed, NASA's five-year budget request for Earth Science is about $1.4 bil-

lion annually, representing a significant Administration priority. NASA remains the largest federal contributor to the Climate Change Research Initiative. Approximately 40 percent of the FY05 Earth Science budget will go towards research on data from 80 sensors supported by NASA's 18 Earth-observing satellites. NPOESS Preparatory Project (NPP), used to harness NASA satellite data for global climate change observations, increased funding by 36 percent for FY 2005. The Orbiting Carbon Observatory (OCO), which relies on space-based platforms to measure atmospheric levels of carbon dioxide that generate data for the enforcement of emissions standards, was increased by 37 percent in FY 2005.

NASA's budget for Structure and Evolution of the Universe averages $400 million annually over the next five years. The budget for Sun-Earth Connection ramps up to $1 billion over the next five years. While some previously planned work has been deferred, these activities remain significant strategic objectives of the Agency.

Aeronautics funding remains a priority for NASA, and has not been reduced as a result of the Vision for Space Exploration. A minor dip in the budget in FY 2005 represents a planned project completion in FY 2004. In addition, in FY 2004 Congress added $88 million for Congressional earmarks, which are not reflected in the FY 2005 budget request for NASA..

Q3. After the Shuttle program ends in 2010, Russia will have a monopoly in providing crew transport to and from the Space Station. How will you ensure access to Soyuz vehicles at a reasonable price?

A3. The ISS Partnership is currently engaged in detailed discussions on the selection of an ISS configuration. As part of this process, the Partnership is assessing any implications to the program resulting from the new U.S. Vision for Space Exploration, including retirement of the Space Shuttle. (The Shuttle is slated for retirement upon completion of Station, which is planned for 2010.) In the event that any acquisition of Soyuz services from Russia are required to fulfill U.S. obligations to the international partnership it will be conducted in accordance with the U.S. Federal Acquisition Regulations and all other applicable U.S. laws and regulations. As with past acquisitions for the ISS program from Russian sources, the reasonableness of the price will be a central part of the negotiations.

Q3a. The President has basically told the civil servants and contractors working on the Shuttle program that their jobs will be gone in six years. The best employees will start leaving first. Yet the Shuttle still has to fly safely over that entire period (some 25 to 30 flights). What is your plan for ensuring that you will retain the critical skills and focus needed to fly the Shuttle safely in the midst of such change?

A3a. Our contractors have the requirement to hire appropriately skilled personnel or train them to meet all the conditions of the contracts. They have been hiring or training to meet and maintain our skill level requirements and this trend is anticipated to continue. As the Space Shuttle program nears retirement, we fully anticipate that aerospace technician employment opportunities will continue with NASA, driven in part by the Vision for Space Exploration and the continuing need to support the International Space Station.

NASA understands the challenges of maintaining an incentivized workforce as the Shuttle Program phases down. We are beginning to develop a plan to ensure that the skills required to maintain a safe and reliable fleet are in place until the last Space Shuttle flight has completed its mission.

The retirement of the Space Shuttle is not the end of the space program but rather the beginning of an opportunity to transition a highly skilled workforce into programs requiring their skills and challenging their creativity. We believe, at the appropriate time, these workers who have Shuttle experience will be able to continue to work with NASA on new programs requiring their unique skills.

Q3b. How much do you estimate it will cost?

A3b. While we currently do not anticipate increased costs associated with maintaining critical skills as the Space Shuttle program draws down, there are still too many unknowns at this point.

Q3c. If you do not know now, when will you have such a plan and cost estimate completed?

A3c. As noted above, we are just beginning to develop a plan to ensure that we maintain the critical skills and focus necessary to safely fly the Shuttle until its retirement. At this time, we cannot provide an estimate of when the plan and cost estimate will be complete.

Q4. After the Shuttle is retired in 2010, there will be no way to get any major pieces of failed Space Station hardware back to Earth to be repaired and refurbished. Since that had been the maintenance and repair philosophy for the Space Station, how much will you have to spend acquiring sufficient "throwaway" spare parts? Where is that "book-kept" in the Space Station budget?

A4. Based on the Vision for Space Exploration, NASA is refining its projections for ISS cargo and crew support (including spare parts). This activity is being done in concert with developing an integrated strategy for using a range of domestic and international assets for transportation to and from the Station. Once a comparison is made between future logistics needs and the capabilities of existing and potential transportation assets, NASA will determine if additional spares will be required, what their projected cost will be, and whether the costs can be accommodated within projected program budget reserves.

Q5. The President's plan does not set any timetable for sending humans to Mars. Based on your assumed inflationary growth budget plan and all of the lunar activities you have planned, what is the earliest date at which a human mission to Mars would be possible from a budgetary standpoint?

A5. Before the timeline for a human mission to Mars can be established, a number of steps must be completed. First, to get the range of possible dates, architectural concepts will have to be developed based on extensive and rigorous trade studies. Second, to narrow the possible dates, many scientific, risk-reduction, and technology demonstration missions will have to be conducted.

Multiple architectural concepts for conducting a human Mars mission are currently under development. These options will identify trade studies and options for conducting precursor robotic or human demonstrations in relevant environments including the Lunar surface. New concepts will be developed by soliciting ideas from industry, academia, NASA, and other sources. Mission concepts will be scientific and discovery driven, and will maximize the potential of robots and humans working together towards the Vision for Space Exploration.

Many important steps will be taken along the way to Mars, including development flights of a new Crew Exploration Vehicle, robotic missions to the Moon, and human missions to the Moon. In parallel, robotic missions to Mars will continue to identify key scientific goals for future human missions. Robotic missions to Mars in this decade include the Mars Reconnaissance Orbiter (MRO) in 2005, and the telecom orbiter and Mars Science Laboratory (MSL) in 2009. Mars sample return missions and the "Safe on Mars" missions are planned for the following decade. As these precursor missions evolve, their results in terms of technology demonstrations will enable the establishment of the timeline for a human mission to Mars.

Q6. When will the permanent ISS crew be expanded beyond three people to support the restructured research agenda? Your response to Mr. Gordon's written question on that topic states: "We fully anticipate increasing the crew size beyond three when feasible, in order to increase the ISS's research productivity." What does "when feasible" *mean? What determines when it is feasible?*

A6. There are two critical factors to growth beyond three crew; these are life support and crew rescue capability. Crew rescue for a crew greater than three will require a second Soyuz spacecraft docked to the ISS. Continued provision of the Soyuz is an issue that is being worked across the Partnership and has several solution paths.

The current Environmental Control and Life Support (ECLSS) system on-orbit is capable of maintaining three crew. To grow beyond three crew, additional ECLSS capacity and habitability elements are required. NASA has been continuing development of regenerative ECSLS elements to meet this requirement.

NASA is presently evaluating the options for launch and on-orbit accommodation of the regenerative ECLSS and habitability elements. These studies will be concluded in the fall of 2004 with the selection of a feasible assembly sequence option, which includes capability for growth beyond three crew.

Q7. Under your plan, a Crew Exploration Vehicle (CEV) capable of carrying humans into low-Earth orbit won't be available for another 10 years. *It only took* eight *years to get humans to the Moon in the 1960s. Before NASA suspended the Orbital Space Plane (OSP) program, you were saying that you thought the OSP could be ready to carry humans into low-Earth orbit in* six *years.*

The pace of the CEV program seems to be driven solely by the budget, especially since the development funding is largely flat over the next five years. Is that accurate? If not, why does it take ten years to develop the CEV?

A7. The budget phasing will impact the CEV schedule, but NASA is committed to realizing the Vision for Space Exploration without substantial augmentation of NASA's existing budget. More importantly, NASA will organize its exploration program so that it does not require major new commitments of funding in future administrations. The success of the CEV, in respect to capability and affordability, is significantly driven by the development of sound requirements from the beginning. The CEV will be one critical element in an overall transportation architecture that must work together as a system of systems to support long-range goals for human exploration. Architecture studies and the process of developing requirements will define the CEV interfaces and its relationship to the many supporting elements of the exploration transportation system. The budget phasing supports this process. The CEV program will start in 2006, with the initiation of the design and development process towards the first human flight in 2014. Selection of a single concept for detailed design and development will occur in 2008.

Q8. NASA's FY 2005 budget request sets aside $140 million for additional cargo and crew services. The Russian Soyuz is the only non-Shuttle means of providing crew services. Historically, legislation provides that funds appropriated to NASA must be spent within two fiscal years, which means that this $140 million would need to be obligated either in FY 2005 or FY 2006. However, the Iran Non-Proliferation Act makes it illegal to expend these funds for additional Soyuz services during those two years.

Q8a. How do you explain this discrepancy?

A8a. The FY 2005 performance goal for this project, as submitted in the 2005 Budget Estimates, is to "baseline a strategy and initiate procurement of cargo delivery service to the ISS." This would be an augmentation of current Shuttle capability using commercially procured services, and could include domestic capabilities if available, or foreign capabilities such as the ATV.

Q8b. Do you agree that expending these funds in FY 2005 or FY 2006 on Soyuz or Progress services would require a legislative change to the INA?

A8b. NASA is aware of the provisions of the INA and will work with Congress to resolve any issues associated with it.

Questions submitted by Representative Brad Sherman

Q1. According to NASA's budget plan, the President's exploration initiative is estimated to cost close to $200 billion over the next 15 years, with more costs incurred after that time. Why is this investment better than investing the same amount of money in energy R&D, with the goal of making the U.S. energy independent? Which of the two alternative investments do you think would deliver a greater benefit to the American economy and to overall societal goals?

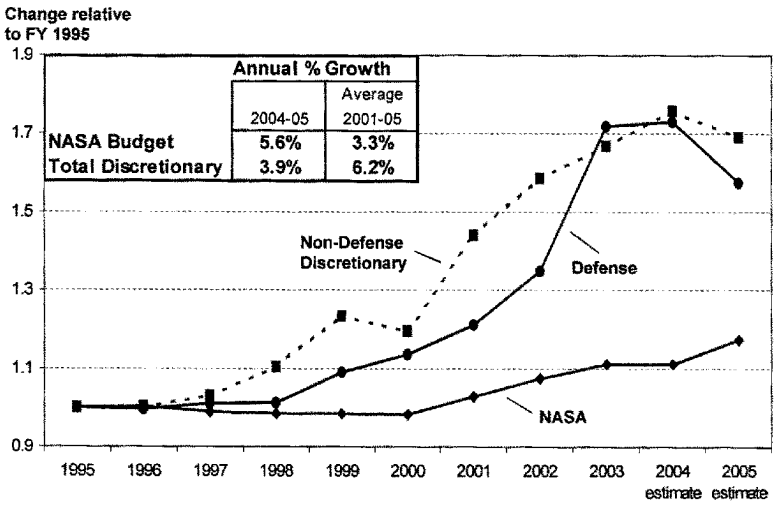
A1.

It is Affordable—The budget fits within the goals of reducing the deficit by half over five years and constraining discretionary growth.

Represents 0.7 percent of Federal Budget vs. 1.0 percent in 1994 and over four percent peak during Apollo.

From FY 1995 through the FY 2005 request, NASA budget increase is *one-fourth* the rate of overall non-defense discretionary spending—17 percent compared to 69 percent.

Federal Spending Comparison



It is Achievable—The vision can be accomplished within the long-term funding plans, and it builds on NASA's recent successes and demonstrated management reforms.

Space Station program now under control, demonstrating solid resource management.

Mars Exploration Rovers successes highlight NASA's technical and management skills.

NASA is *leading* implementation of the President's Management Agenda in two areas government-wide, and has improved in more areas than any other federal agency.

It is Focused—The budget aligns programs with the vision goals, affirms the Nation's commitment to space exploration and provides a clear direction for the civil space program.

Vision responds to concerns expressed by the *Columbia* Accident Investigation Board (CAIB), Congress, and elsewhere on the need for a long-term vision for human space exploration.

Vision encompasses human and robotic missions and includes pursuit of multiple destinations, including the return of humans to Moon.

Activities will be paced by experience, technology readiness, and affordability.

Implementation begins now with key missions that are already in progress, such as Mars exploration, visits to other solar system targets, and Space Station research.

It is Compelling—The budget fully supports the vision for space exploration and supports other mission priorities such as Aeronautics and Earth Science.

Exploration of the solar system and beyond will be guided by compelling questions of scientific and societal importance.

NASA exploration programs will seek profound answers to questions of our origins, whether life exists beyond Earth, and how we could live on other worlds.

It Funds Critical Near-Term Priorities in Space Shuttle Return-to-Flight and Space Station–Space Shuttle Return-to-Flight and Space Station account for 85 percent of the FY 2005 increase.

- $374M increase for Shuttle, to safely return to flight and continue assembly and operations of the Space Station.

- $365M increase for Space Station to continue assembly and operations, due primarily to new funding for crew & cargo services and needed reserves, and $200M appropriation cut in FY 2004.

Questions submitted by Representative Mark Udall

Q1. In your response to my question on the timetable for having the autonomous repair capability (ARC) required for the Hubble Space Telescope (HST) servicing mission, you stated: "The autonomous repair capacity has to be demonstrated on the first two flights. That is our objective." *From the projected annual Shuttle flight rate and the projected availability of ARC, the HST servicing mission could proceed safely as planned in 2006. While there may be uncertainty as to whether a successful demonstration will occur on that timetable, that uncertainty affects planning for Shuttle missions to both HST and the International Space Station.*

Given these facts, wouldn't it make sense to continue planning for the servicing mission in the same manner as planning is continuing for Shuttle missions to the Space Station, pending demonstration of the repair capability?

A1. The decision to cancel the Hubble SM–4 servicing mission was made after evaluating the requirements that came from safety recommendations of the *Columbia* Accident Investigation Board (CAIB) report. NASA rigorously examined the on orbit inspection techniques and repair methods that are required to ensure adequate mission safety. NASA determined that safe inspection techniques and repair methods could be developed for use on the Shuttle while docked at the International Space Station (ISS) because of the safe haven capabilities of the ISS and because the Space Station Remote Manipulator System (SSRMS) would be available to assist with inspection and repairs.

For the scenario of the Shuttle in a non-Station orbit (like the HST servicing mission), NASA determined that it would have to develop unique, single use technologies and tools in order to be able to accomplish the needed inspection techniques and repair methods. It is unlikely the new technology needed to service Hubble would be ready before critical Hubble systems fail (Gyroscopes will probably fail by late 2006; the battery is expected to fall below needed capacity in about 2008).

NASA would also have to dedicate two Shuttles for a servicing mission to comply with safety recommendations of the CAIB for a non-Station mission. NASA would need a second Shuttle positioned for launch, which would require an unprecedented double workload for ground crews. The rescue, if required, would involve a Shuttle-to-Shuttle crew transfer with unproven techniques. All this would have to be done under extreme schedule pressure, because Shuttle life support, food and water are limited. On a non-Station autonomous mission, the crew would only have two to four weeks before the rescue Shuttle would have to arrive.

NASA issued a formal "Request for Information" (RFI) on February 20, 2004, to solicit from industry, academia, or anyone who may have useful information bearing on how to extend the useful scientific lifetime of the Hubble. NASA received 26 responses, which are being evaluated at this time. A plan will be developed when a decision is made as to the approach the Agency will take to prolong the life of Hubble.

NASA has also formally requested a study by the National Academy of Sciences to ensure we have fully considered all reasonable alternatives to finding the best way to extend the lifetime of the Hubble Space Telescope.

Q2. In your written testimony, you cite the failure of the NRC's 2001 Decadal Survey to recommend new missions in the Hubble wavelength regime as a scientific rationale for not pursuing the SM–4 HST servicing mission. However, isn't it true that the Decadal Survey assumed that the Hubble Space Telescope would continue to operate until the end of this decade and that it endorsed NASA's decision to continue HST operations through this decade? If this is true, why do you cite the Decadal Survey?

A2. The difficult decision to not proceed with an HST servicing mission was made after careful review of risk issues following the tragic loss of the *Columbia* Space Shuttle and crew. The safety recommendations of the *Columbia* Accident Investigation Board were used as our guide, along with our progress in meeting the recommendations in our return-to-flight activities. Safety, not science, was the reason for the cancellation.

It is true that the decadal survey endorsed NASA's plan to operate Hubble to the end of the decade, at reduced operating cost for the final years. This, however, assumed normal Shuttle operations and a Shuttle servicing mission by or before 2004.

The decadal survey endorsed a different wavelength band, infrared, for the next large space telescope (now known as JWST). It now appears, with current projections, that with judicious use of the telescope's battery power, HST will continue to operate for three to four more years, even without a servicing mission. Furthermore, NASA is now studying and considering a robotic mission to service Hubble. Such a mission could extend Hubble's mission even beyond the end of the decade.

Q3. What countries have been approached about their willingness to participate in the new human space flight vision? What have their reactions been? What additional countries do you intend to approach? What is the U.S. government's current position on whether China is eligible to participate in significant human space flight activities with NASA? Would you in fact welcome China's participation in this initiative?

A3. NASA has not formally approached any other nations about specific participation in the human missions called for in the Vision for Space Exploration. NASA has discussed the Vision with current space partners and with other nations that have expressed interest. NASA is continuing preliminary discussions with prospective partners, and is now considering the advice of the President's Commission on Moon, Mars, and Beyond (Aldridge Commission) on international participation before proceeding more vigorously. Reactions to the vision thus far have been favorable. The European Space Agency has initiated a formal process to consider its participation in the Vision.

No country, including China, has been excluded from participation at this stage. If Chinese participation advances the goals of the Vision and is consistent with broader U.S. policy objectives, NASA will consider it at the appropriate time.

Q4. What is the scientific rationale for the President's initiative? How much of that rationale will be satisfied by planned robotic missions, and how much will require human explorers? From a scientific standpoint, what objectives specifically require human explorers?

A4. The science content of the President's exploration initiative flows directly from and enhances the science agenda formally presented in the NASA 2003 Strategic Plan. Specifically, the Vision for U.S. Space Exploration advances exploration of the solar system and beyond, promotes the search for life in the universe and extends life beyond our home planet.

Robotic Precursors

The initial steps in the President's initiative must be undertaken robotically, just as the precursor missions to the Apollo human expeditions were undertaken in the 1960's. Specifically, the ongoing Mars Exploration Program will intensify its efforts to understand the potential habitability of Mars, chart the potential resources that may help enable human exploration of the red planet, and establish a knowledge-base for understanding the modern Martian environment (i.e., weather, climate, dust, toxic components, etc.). This is already underway thanks to the Spirit and Opportunity rover missions, the ongoing activities of the Mars Global Surveyor and Odyssey orbiters, and with the 2005 launch of the Mars Reconnaissance Orbiter, which will help chart landing sites that may one day serve as the places the first humans on Mars must visit. In addition, the President's initiative calls for a robotic lunar exploration program, which will be guided by applied science/engineering drivers to return humans to the lunar surface no later than 2020. The first specific lunar mission will be the Lunar Reconnaissance Orbiter (LRO), which NASA will launch in 2008. This mission will chart the Moon using the latest in measurement devices, searching for resources such as water ices, and developing the knowledge of what it will take to land both robots and humans on the Moon in new places, as a stepping stone to getting people to Mars. LRO will establish a high precision global map of the Moon necessary for safe landings and discover what lies in the permanently shadowed regions of the planet. Many LRO measurements will support ongoing science priorities recommended to NASA by the National Academy of Sciences for the Inner Planets of the Solar System.

Human Exploration of the Moon

Once the robotic precursors have identified the most compelling and safe places for human-based exploration, human explorers will venture to the Moon to new kinds of places, much more directly aligned with the kinds of activities humans will have to undertake on Mars. The first human explorers will serve as highly adaptable field samplers, collecting invaluable materials for both on-site analysis (in prototype surface laboratories) and for more detailed analysis back on Earth. They will set up equipment as precursors for what will have to be done on Mars, perhaps in-

cluding drilling devices for accessing the subsurface to depths of 30 feet or more, where even more compelling scientific materials may be isolated. In addition, they will undertake life sciences experiments designed to conduct experiments necessary to understand (and ultimately to predict) how living systems respond to variable gravity and deep space radiation. These keystone measurements and experiments will serve as both scientific and operational stepping-stones toward the more challenging goals of sending humans to Mars, where they will undertake activities that seek to understand whether Mars ever harbored life as we presently understand it. One example (of many) of an activity that humans are uniquely suited for, on the Moon or Mars, would be in situ radiometric age determination of rocks. This sort of analysis requires careful sample selection, preparation, handling, and subsequent analysis in complex instrumentation such as mass spectrometers. Humans could conduct the first field-based assessments of the absolute ages of lunar (and later Martian) surface materials for the purpose of understanding the chronology of key Solar System events, including gigantic impacts (such as those that formed the impact basins). The timing of such events is critical to understanding any record of life on planets such as Mars, and for using the Moon as a key stepping-stone.

Scientific Goals on Mars

In 2000, the Mars Exploration Payload Assessment Group established a set of scientific goals for Mars exploration at a series of meetings and workshops that involved more than 110 individuals from universities, research centers and organizations, industry, and international partners. The primary scientific goals are: the search for life, evaluation of Mars geology, and studies of Martian climates. The following discussion considers the implications of pursuing the first of these goals, and the potential advantage of using humans on location.

We will attempt to establish if there is, or ever was, life on Mars. The investigation of life on Mars has at least three possible outcomes: (1) Life arose independently and different from life on Earth; (2) Life arose just like life on Earth, but evolved differently; or (3) There is no evidence of life ever existing on Mars.

If we find that there was or is life that arose independently on Mars, then we have answered the big question—we are not alone. It also implies the broader search for life throughout the universe should bear fruit—there is a lot of life in the universe. If it can evolve independently in two places, then it is going to be present in billions of places.

Furthermore, suppose the life we find is not based on nucleic acids, as every form of life on Earth is. Suppose it is protein based (it will almost certainly be carbon-based, since no other element has the stability and complex covalent bonding of carbon) instead of nucleic acid based. It would be simply the biggest scientific discovery ever made.

Suppose we find that there is life but it did not develop independently, instead Mars seeded Earth or vice-versa. Again, an astounding discovery and the differences in subsequent evolution would reveal incredible things about how life occurred and evolved on Earth.

Suppose we do not discover life on Mars. How can it be that life did not arise in a place with water and all the elements necessary for life? What was so different on Mars from the Earth? There is plenty of life on the Earth that lives in much harsher conditions than Mars. Extremophiles live in water that is hotter than steam (doesn't boil due to being deep underwater, therefore under high pressure), other life lives where the pH is that of hydrochloric acid, others with pH of ammonia. Life is tough stuff. Was there some event in Earth's past that made life begin here? If we find no life on Mars, then it is possible we really are alone. Earth could contain all the life in the universe. If that is true, then insuring our survival as a species is transformed from an important, somewhat egocentric goal to what must be considered a universal imperative.

Role of People in Pursuing Science on Mars

The very character of research begins with the ability to observe, to be able to recognize something new and valuable, and then to envision a new direction that so often cannot be anticipated by or pre-programmed into a computer.

The crew provide feedback that machines cannot—they participate, they think, they observe, they "feel." They use all five senses, and interpret and respond to these senses. People can anticipate problems and be proactive (whereas computers are only reactive); people are our eyewitnesses to discovery.

People are needed in space research because any research—in space or on the ground—requires human abilities that exceed the capabilities of modern machines. We must be able to observe, adapt, overcome unforeseeable obstacles, and recognize serendipity. These things cannot be programmed into machines.

Direct human intervention remains indispensable in four specific areas:

Creative input in response to observed and unexplained space-based phenomena requiring specific scientific expertise

Instrumental dexterity combined with human judgment in order to carry out complex activities specific to working in a microgravity environment

Troubleshooting and repair activities not feasible through automation

Inspiration and sharing of experience: The most common question about space flight is "How does it feel?" Astronauts bring the experience of "being there" to people all over the world.

The first step is observation and appropriate sampling. Consider taking a walk, first a human walk, then a robotic one. A woman is walking along and sees an interesting patch of orange on a rock. She goes to the rock, takes a picture, and notices that the orange area has varied patterns of texture. She touches a few locations without much reaction but suddenly finds a spot that starts to crumple and give off a vapor when touched. She quickly grabs a sample container, fills it with material from the crumbling area, and then uses a tool to carefully extract a similar looking area, along with its surrounding structures, without touching it directly. She walks along a little further and feels something soft beneath her feet. Looking down she sees a patch of material that looks like dry moss. The part she stepped on is dissolving but there is another tiny patch nearby that she carefully scoops up for a sample. She goes on to find samples under rocks, inside crevices, on top of walls.

Now consider sitting by a monitor on Earth operating a robot taking a similar walk. We spot the interesting patch of orange on the rock. Of course, by the time we see it, our robot has already walked past it for fifteen minutes. We send the command to turn around, retrace the path for 30 minutes (since that is when our command will get there), and then wait. 30 minutes later we see that the robot got our command and turned around. 30 minutes later we see the area near the interesting rock. Now we command the robot to go to the rock and wait. 30 minutes later we tell the robot to touch an interesting spot. 30 minutes later we learn that spot is solid, not very interesting. We command the robot to touch several spots. 30 minutes later we see a couple of the spots we touched crumple, give off vapor, and dry up. 30 minutes later we tell the robot to touch 10 more spots and immediately sample every spot touched. 30 minutes later we see if we wasted 10 sample containers or if we got a good sample. Unfortunately, we may not be able to carefully extract a similar looking area, along with surrounding structures, because our robot is not dexterous enough or because the 30 minute feedback is too slow to react to crumbling or cracking that occurs in the extraction. By now it is getting dark and we have used all our sample containers so we go back to return our samples to the lab. Perhaps we drive over the dry mossy patch but we do not notice the change in surface texture so we miss an opportunity. Or perhaps we have a very sophisticated robot and we do notice the change in texture. Then, 15 minutes later. . ..

Back in the laboratory, we have to analyze the samples. We try various techniques including microscopy and biochemical analysis. However, life on Mars may not look or act like life on Earth at all. It may not need water. It may not even contain DNA or RNA or even any nucleic acids. If we find a promising specimen, we would like to get it to grow. How do you feed something that doesn't use proteins, fats, or carbohydrates? We may need to build a terrarium that is highly specific to the ecology where we obtained the sample. Even that may not succeed so we may need to bring our culture materials out in the field and set them up within the ecology of our specimen. We may need to catch transient findings—perhaps the sample will be dying before our eyes. We may need to create new tests in response to our results—perhaps we need different pieces of equipment and have to cannibalize an instrument to build a new one. These are tasks that require humans for success.

Appendix 2:

Additional Material for the Record

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CRS Report for Congress
Received through the CRS Web

Space Exploration: Overview of President Bush's New Exploration Initiative for NASA, and Key Issues for Congress

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Summary

On January 14, 2004, President George W. Bush set new goals for the U.S. space program, asserting that the United States should continue exploring the solar system "because the desire to explore and understand is part of our character." The vision he outlined for the National Aeronautics and Space Administration (NASA) focuses on the goal of returning humans to the Moon in the 2015-2020 time frame, and eventually sending them to Mars and "worlds beyond." Under the plan, the space shuttle would be retired after construction of the International Space Station (ISS) is completed in 2010, and the United States would end its involvement in ISS by FY2017. NASA's FY2005 budget request shows that $12.6 billion would be "added" for FY2005-2009 to begin achieving the new goals, but only $1 billion is new money; the remainder would be redirected from other NASA programs. A cost estimate for the entire program was not provided. The President invited other countries to join in the program. Congress is evaluating the President's proposal. This report will be updated regularly.

Overview of President George W. Bush's Exploration Initiative

On January 14, 2004, President George W. Bush announced new goals for the U.S. space program [http://www.whitehouse.gov/news/releases/2004/01/20040114-3.html]. Amplified by documents from the White House Office of Science and Technology Policy (OSTP) [http://www.ostp.gov] and NASA, the following are its main features.

- Astronauts would return to the Moon in the 2015-2020 time period. (The last Americans walked on the Moon in 1972.) NASA would build a Crew Exploration Vehicle whose primary purpose would be to take astronauts to the Moon. It would be available for human space flights in 2014, and could be used to take astronauts to the International Space Station (see CRS Issue Brief IB93017) as well.

- Eventually, astronauts would go to Mars, and "worlds beyond," but no date was announced.

- Robotic probes would be used as trailblazers for human explorers. The first probe in support of this exploration initiative would be launched in 2008 to study the Moon further.

- Construction of the International Space Station (ISS), using the space shuttle, would be completed by 2010. The shuttle system (see CRS Issue Brief IB93062) then would be retired. The President promised that the United States would meet its obligations to its partners in the ISS program (Europe, Canada, Japan, and Russia).[1] According to a NASA budget chart released the day of the President's speech, U.S. involvement in ISS would end by FY2017. Between 2010 and 2014 when the Crew Exploration Vehicle is available, U.S. astronauts would rely on other ISS partners (presumably Russia, the only ISS partner with a capability to launch humans into space) to take them to and from ISS.

- NASA would redirect its research aboard the ISS to that which specifically supports human exploration of space, instead of the broadly based, multidisciplinary research program that had been planned.

- Other countries were invited to participate. None were identified, but NASA made clear that it is not limited only to those participating in ISS.

- NASA FY2005 budget documents show that $12.6 billion would be "added" to its budget for FY2005-2009 to begin achieving the new goals, and a NASA budget chart suggests that $150-170 billion would be devoted to the initiative from FY2004-2020 (NASA declines to give a specific figure). Most of the money comes from other NASA programs. The $12.6 billion, for example, is comprised of $1 billion in new money for FY2005-2009, with $11.6 billion redirected from existing NASA activities. These numbers must be used cautiously, however, because they are based on a NASA assumption that without the President's initiative, NASA would have been held to a flat budget for those five years. The "increase," therefore, is above a hypothetical budget that is lower than what NASA projected in its FY2004 budget. Also, NASA budget materials describe the entire NASA budget request for FY2005-2009 ($87.1 billion) as the budget for the "exploration vision," of which $31.4 billion is "exploration specific." Thus it is difficult to determine exactly how much the President is proposing to spend on this initiative.

- A Commission on the Implementation of U.S. Space Exploration Policy was created by the President to advise NASA on implementation of the policy. It is headed by Mr. E.C. "Pete" Aldridge, a former DOD official.

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[1] Those obligations are detailed in the ISS Intergovernmental Agreement (IGA) signed in 1998, and associated Memoranda of Understanding between NASA and its counterpart agencies. The texts are available at: [http://www.hq.nasa.gov/office/codei/].

Rationale. The President's speech came 11 months after the tragedy of the February 2003 space shuttle *Columbia* accident (see CRS Report RS21408), and 2 weeks after the January 3, 2004 successful landing of a U.S. robotic probe (Spirit) on Mars. Invoking the explorations of Lewis and Clark, the President explained that America has ventured into space for the same reasons, "because the desire to explore and understand is part of our character. And that quest has brought tangible benefits that improve our lives in countless ways." The President said that returning to the Moon was an important step for the space program because establishing an extended human presence on the Moon could vastly reduce the costs of further space exploration. Since the Moon has less gravity than Earth, spacecraft assembled and provisioned there could be launched using less energy, and therefore at lower cost, according to the President.

Initial Reaction. An Associated Press-Ipsos poll conducted several days (January 9-11) before the President's speech, in response to press reports that the announcement was imminent, found 48% of the respondents in favor of a Moon/Mars program, 48% opposed, and 4% not sure.[2] AP reported that most respondents generally favored continuing to send humans into space, but 55% said they would prefer spending money on programs such as education and health care instead of space research. Reaction by Congress also has been mixed. In separate press releases, House Science Committee Chairman Sherwood Boehlert and Ranking Democrat Bart Gordon said they welcomed the statement of vision from the President, but awaited details on subjects such as timetables, funding, and the impact on other NASA programs. The Senate Commerce Committee held a hearing on January 28, 2004, at which concern was expressed about the potential cost of the initiative, and its impact on other NASA activities. A House Science Committee hearing is scheduled for February 12, 2004.

Comparison with President George H.W. Bush's 1989 Space Exploration Initiative

Although some media stories portray the current President Bush's speech as the first new vision for NASA since the Apollo era,[3] President George H.W. Bush made a similar proposal in 1989. On July 20, 1989, the 20th anniversary of the first human landing the Moon, the senior President Bush announced that Americans would return to the Moon

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[2] (1) Associated Press. Results of AP Poll on Space Exploration. January 12, 2004, 14:44. (2) Lester, Will. AP Poll: U.S. Tepid on Bush's Space Plans. Associated Press, January 12, 2004, 14:50.

[3] The Apollo program was initiated by President John F. Kennedy in May 1961 to land a man on the Moon and return him safely to Earth before the end of that decade. NASA first developed experience with launching people into space, and extravehicular activities (EVAs, or spacewalks), through the Mercury (1961-1963) and Gemini (1965-1966) programs. The first Apollo mission was to be launched in 1967, but the crew died on January 27, 1967 when a fire erupted in the Apollo command module during a pre-launch test. The first successful Apollo mission was launched in 1968, and the first Americans landed on the Moon on July 20, 1969 (Neil Armstrong and Buzz Aldrin, while pilot Michael Collins orbited above in the Apollo 11 spacecraft). A total of six two-man crews walked on the Moon from 1969-1972. Another crew (Apollo 13) intended to land on the Moon in 1970, but made an emergency return to Earth when the Service Module of their spacecraft exploded enroute to the Moon.

and go on to Mars. He said: "Why the Moon? Why Mars? Because it is humanity's destiny to strive, to seek, to find. And because it is America's destiny to lead."

Major Features of the 1989 "Space Exploration Initiative". The program was known as the Space Exploration Initiative (SEI). The major goals were building the space station as a stepping stone to returning humans to the Moon and someday sending them to Mars, though dates were not set. In response to congressional criticism that the plan lacked specifics, the senior President Bush gave a speech in May 1990 adding more detail, including that he believed humans would reach Mars by 2019.

Richard Darman, then Director of the Office of Management and Budget (OMB), stated at a press conference the day of the President's speech that fulfilling the goals would cost $400 billion over 30 years. Other cost estimates (some higher, some lower) were offered later by NASA, but no decision was made on exactly how to proceed, so detailed cost estimates were not provided. Mr. Darman's original estimate continues to be the one most often associated with the SEI program. NASA was the lead agency for SEI, but it also involved the Department of Defense (DOD) and Department of Energy (DOE), which were involved primarily because of their work with NASA on a program (SP-100) to develop new nuclear power systems for space missions.

Congressional Reaction to SEI. The initiative was announced during a period when Congress was attempting to cut government spending to reduce the federal deficit, and it was not received enthusiastically. Funding for SEI was requested in the FY1991, FY1992, and FY1993 budgets, though what constituted "SEI funding" changed significantly during those years. In the FY1991 request, OMB used a "maximalist" definition, labeling a number of existing programs in the NASA and DOD budgets as related to SEI. As opposition to the program grew, however, it became prudent to narrow the list of activities related to SEI and a "minimalist" definition was used in the FY1992 and FY1993 budgets. Thus, tracing SEI funding is complicated. The following account is limited to the NASA budget, since it was the lead agency for the program.

Under the "maximalist" definition used for FY1991, $953 million was requested for NASA. The FY1991 NASA authorization bill (P.L. 101-611) approved almost full funding, but the appropriations bill essentially zeroed it (P.L. 101-507). Congress subsequently allowed NASA to reprogram $37 million into SEI for FY1991. For FY1992, using the "minimalist" definition, the NASA request for SEI was $94 million. Congress approved $32 million. For FY1993, the definition was revised again, and $64 million was requested for NASA. The FY1993 NASA authorization bill (P.L. 102-588) approved approximately half of the request; the appropriations bill (P.L. 102-389) essentially zeroed it.

Similarities and Differences in the 1989 and 2004 Proposals. The senior President Bush's long term space goals were very similar to those enunciated by the current President Bush — return humans to the Moon and someday send them to Mars (although the current President Bush added that they also would go to "worlds beyond"). One difference is that the senior President Bush heralded the space station program, on which construction had not yet begun, as a stepping stone to the Moon/Mars goals. Today, construction of the space station is underway, and the space shuttle has suffered another catastrophic accident. (The shuttle's first accident, the explosion of *Challenger*

73 seconds after launch, was in 1986.) Thus, the current President Bush's plan sets end dates for both the space shuttle and space station programs.

Another similarity is that the 1989 announcement was made when the federal budget deficit was high ($152.5 billion), as it is today ($521 billion). However, Congressional Quarterly (CQ) points out that the political climate associated with deficits is not the same in 2004 : "...when Ronald Reagan and the senior George Bush were in the White House and Democrats controlled the House with an iron fist, there was always a public bow to the idea of balancing the budget....The new Bush administration has already signaled that a balanced budget is no longer its desired objective.... The [FY2005] budget will probably project a reduced deficit by fiscal 2009, to something near $250 billion and 2 percent of GDP. There's no political imperative, at least, to take it down any further than that.... (CQ Weekly, January 17, 2004, p. 131.) Thus, although the new initiative comes at a time of deep budget deficits, that does not necessarily mean the proposal will meet the same fate, although cost is certain to be a major issue as Congress debates its merits.

Key Issues for Congress

Although most media accounts of the Bush initiative focus on the long term "Moon/Mars" goals, nearer term questions of how long to fly the space shuttle and utilize the International Space Station, and what NASA activities might be cut in order to pay for the new goals, may be the immediate focus of congressional attention. Among the questions that could be asked are:

What Are the Implications of Terminating the Shuttle Program in 2010? The space shuttle has made 113 flights, two of which ended in tragedy — *Challenger* in 1986 and *Columbia* in 2003. The *Columbia* Accident Investigation Board (CAIB) endorsed returning the shuttle to flight, but said that if NASA plans to use it beyond 2010, it must be recertified. The shuttle is the only U.S. vehicle capable of taking astronauts to and from space. President Bush said the shuttle would be retired when space station construction is completed in 2010. A new Crew Exploration Vehicle would be developed, and fully operational for Earth orbital missions by 2014.

- What would be the consequences of a 4-year hiatus in U.S. human spaceflights (2010-2014)? How much would Russia charge for taking U.S. astronauts to and from ISS, and how would NASA pay (the Iran Nonproliferation Act, P.L. 106-178, prohibits NASA from paying Russia for ISS-related activities unless Russia stops proliferating certain technologies to Iran)? Would China be considered as an alternative now that it can launch people into space?

- What upgrades, if any, to the shuttle should NASA continue to pursue? What new launch vehicles may need to be developed?

- What would happen to the shuttle's workforce of approximately 15,750 contractors and 1,700 civil servants?

- How would NASA meet its commitments to the other ISS partners without the shuttle to take crews and cargo to and from ISS during the operational period?

- Alternatively, if the shuttle is not terminated in 2010 as the President proposed, how much would it cost to recertify it?

- If the "Moon/Mars" goal is not adopted, what would be the future of the shuttle? Should it be terminated in 2010 nonetheless?

- What steps must NASA take to ensure that the space shuttle returns safely to flight status, and the shuttle program is not unduly pressured by the new schedule to complete space station construction by 2010? CAIB cited schedule pressure as a factor in the *Columbia* tragedy.

Should U.S. Involvement in ISS End by FY2017? ISS is discussed in CRS Issue Brief IB93017. Construction began in 1998 and is expected to be completed in 2010. Plans had called for ISS to be operated for at least 10 years after construction was complete. Now, NASA funding would end by FY2017, and the research program would be redirected to support only that which is needed for the new initiative.

- Is the taxpayer investment in the space station ($32 billion through FY2003) worth the benefits if the only U.S. research conducted there is related to the "Moon/Mars" goals? What are the lost opportunities in other scientific disciplines of focusing the research on Moon and Mars exploration?

- What will happen to the space station? Will it be turned over to the other partners to make use of as they wish? Will it be "privatized"? Will it be deorbited? If so, how, and at what cost?

- If the "Moon/Mars" goal is not adopted, should NASA return to its plan to use ISS for a broadly-based research program for at least 10 years after construction is completed, or terminate its involvement nonetheless?

What Are the Costs and Other Details of the "Moon/Mars" Goal?

- How much would the Moon/Mars endeavor cost and over how many years? To what extent will Congress support the initiative absent credible cost estimates?

- What would happen to NASA's other programs in aeronautics and space science and technology? What impact might there be on federal funding for non-space related national priorities? The President envisions little added funding for NASA, instead reprioritizing programs within an essentially level NASA budget, adjusted for inflation (FY2004-2020). That might mitigate concerns that the initiative would increase the deficit or take money from other national priorities, but raises issues about the impact on other NASA activities and whether the level of funding is adequate to achieve the goals.

- What role should the private sector play in the exploration initiative?

- What countries should be invited to join? Should China be included? Or India, which has announced plans to send a robotic probe to the Moon? Will other countries be willing to participate if the United States does not live up to its obligations on the ISS program, and if the United States insists on directing how the Moon/Mars program is to be conducted?

- What was learned during the 3 years of work on the earlier Space Exploration Initiative that can be applied to this endeavor?

- To what extent can robotic spacecraft accomplish these exploration goals instead of humans, at less cost and risk to human life?

Space scientists hope that robotic and human missions can coexist as President George W. Bush's new exploration plan sparks an emotional debate over NASA's future

How Much Space for Science?

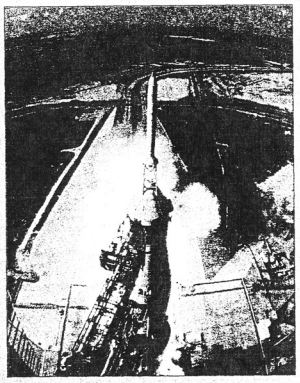
U.S. space science was riding high last November when a group of scientists and engineers gathered at the National Academy of Sciences' conference center in Irvine, California. Their task was to offer advice to the country's ailing human space flight program—a $6-billion-a-year endeavor struggling with a grounded shuttle fleet and a half-completed space station and under heavy fire for poor management and lack of vision.

The contrast with NASA's $4-billion-a-year robotics programs couldn't have been more stark. The Hubble Space Telescope had achieved virtual celebrity status for its spectacular images, two rovers were headed to Mars, and the Cassini probe was gliding toward Saturn. Eager to provide input, the Irvine team suggested that NASA replace the shuttle, refocus station research on human physiology, and plan an exploration program with robots in the vanguard and humans following behind.

The group's advice, released on the morning of 14 January, was astonishingly similar to the vision outlined later that day at NASA Headquarters by U.S. President George W. Bush. What the team didn't anticipate was that NASA's science program might suffer as a result. Human exploration, not science, was the goal, Bush said.

A long-range budget chart unveiled later that day by NASA Administrator Sean O'Keefe appeared to back that up, displaying a new exploration program expanding dramatically in bright blue, whereas "aeronautics and other science activities" were flatlined in dull gray. Two days later came word that no more shuttle missions would be flown to service Hubble, ensuring an earlier end for astronomy's workhorse. "This is a kick in the teeth," says one angry participant in the Irvine meeting. "It's the worst outcome I could imagine."

The speech and its aftermath, coming just days before the first anniversary of Columbia's loss, have rekindled animosities between NASA's science and human space flight communities. They have also divided scientists who stand to benefit directly from Bush's new plan from those who fear losing their research funding. The dispute is sure to spread to Capitol Hill, as legislators take up NASA's budget for next year. The controversy already has reversed a recent warming trend that has seen scientists, from clinical medicine to deep-space astronomy, seeking ways in which astronauts could help further their research goals.



Watch your step. NASA hopes that its new exploration plan will help recapture the heady days of Neil Armstrong's "giant leap for mankind" aboard Apollo 11.

White House and NASA officials insist that the sudden wave of fear and antipathy among researchers is all a terrible misunderstanding. "Don't panic," urges presidential science adviser John Marburger. The Hubble decision was purely about astronaut safety, say NASA managers, and the president's plan for exploration will augment science programs, not undermine them.

But many scientists recall past broken promises involving human space flight programs. "If I were a science guy, I'd try to kill this thing," says one Democratic congressional aide. "These manned programs get out of control and eat everything." That's also how it looks to John McElroy, a retired earth scientist, engineer, and longtime NASA adviser. "The stated schedule is too silly to comment upon, [and] the budget is so ridiculous as to be beneath consideration. I am not given to faith-based space programs."

Of course, many scientists aren't afraid of the human space flight bogeyman. For those who want to study the moon or Mars, Bush's address gave them powerful political protection. And they dismiss the concerns of their colleagues. "For years, scientists have been saying that the human space flight program has no direction," says a disgusted Paul Spudis, a lunar geologist at the Applied Physics Laboratory in Laurel, Maryland, who has proposed a lunar sample-return mission. "Well, now that it does, the whining begins."

Tearing down the wall

The course change proposed by Bush would halt shuttle flights in 2010 and abandon the space station around 2016. Due to safety and scheduling, future flights to Hubble would be cancelled. A new launcher would transport humans to the moon by 2020 and eventually to Mars (*Science*, 23 January, p. 444). Those flights would be preceded by a new series of lunar reconnaissance robotic missions, while the current Mars science effort would continue unabated, and a nuclear technology program would reignite the outer solar system science program. A combination of new money, program reshuffling, and budget cuts would cover the cost, the details of which will appear next week in the Administration's 2005 budget request.

The president's plan marks the first time in 15 years that the space agency has been in the White House limelight. But similar calls for lunar and Mars bases from the current president's father soon fizzled. And the early

1990s were plagued by cost overruns to the space station, delays in shuttle launches, Hubble's myopic mirror, and the inexplicable disappearance of the massive Mars Observer orbiter.

Daniel Goldin was hired in 1992 to untangle the mess, and he spent the decade trumpeting smaller and cheaper spacecraft. There were some successes, notably the landing of the Mars Pathfinder lander and rover in 1997, and space science underwent a renaissance in the latter years of the Clinton Administration. Hubble's scientific triumphs, aided by astronaut mechanics, dazzled the public. Putative evidence that a martian rock contained a fossil excited White House interest in 1996, and individual Mars flights coalesced into a long-term, scientifically vetted, and well-funded exploration plan. Despite the loss of two Mars missions in 1999 and feuding within the solar system robotic program, funding was on the rise and a host of new spacecraft were on the drawing board. But continued troubles with the space station made talk of human missions beyond completion of that facility taboo.

When O'Keefe arrived in December 2001, the former White House budget official imposed strict cost limits on the still-unfinished station but left space science largely alone. Although biological and physical scientists work closely with astronauts, the space science and space flight programs operated virtually as different agencies with vastly different cultures and an ill-concealed distrust of one another. Aside from Hubble servicing missions, they rarely intersected. And both sides liked it that way. "We've been careful in constructing a social, technical, and funding wall between the two," says Daniel Lester, an astronomer at the University of Texas, Austin.

O'Keefe almost immediately began poking holes in the wall, however. He proposed a multibillion-dollar effort to develop sophisticated nuclear power and propulsion systems that would benefit both human and robotic efforts in space (see p. 614). He tried to erase the ancient divisions among field centers and among headquarters offices. And he opened the door to human exploration beyond the low-Earth-orbit space station: At the same time, a small group of space scientists began to explore whether a human presence in space could further their research goals, through construction of large-scale telescopes and even large robotic planetary spacecraft in orbit (see p. 613).

The 1 February 2003 Columbia shuttle disaster put NASA's future onto the president's agenda. A White House interagency team began meeting last summer to consider a new direction for space exploration. Except for Marburger, no senior scientist inside or outside the government was part of that high-level, tightly held discussion led by the National Security Council, according to Administration sources. And although Marburger bristles at the notion that the views of scientists were ignored—"this was not something cooked up by a few people in one corner of the West Wing"—he declines to discuss who was included or even what was discussed.

"The stated schedule is too silly to comment upon, [and] the budget is so ridiculous as to be beneath consideration. I am not given to faith-based space programs." —John McElroy

The labors of senior White House staff shaped the president's speech this month, which labeled robotic missions as "an advance guard to the unknown." Although these machines have proven their worth, Bush said, "the human thirst for knowledge ultimately cannot be satisfied by even the most vivid pictures or the most detailed measurements. We need to examine and touch for ourselves."

"Scientists have been saying that the human space flight program has no direction. Well, now that it does, the whining begins." —Paul Spudis

Spirited response

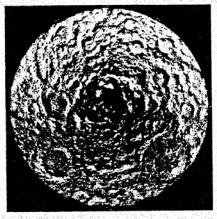
Despite Bush's emphasis on human exploration, the four-page fact sheet accompanying his speech paints a more science-friendly vision of NASA's future. The document backs "robotic exploration across the solar system for scientific purposes," with an emphasis on Mars, the Jupiter system, and asteroids to seek evidence of life, understand solar system history, and pinpoint resources. The plan also supports "advanced telescope searches for Earth-like planets and habitable environments around other stars." That list covers the vast majority of NASA space science. And Marburger says that even the apparent outliers, "like the acceleration of the universe," might fit under the rubric of exploration.

What bothers many researchers, however, is the perception that science is taking a back seat to human flight. "Scientists are saying, 'Hey, wait a minute! We're the ones keeping NASA going,' " says Joseph Alexander, staff director of the National Academy of Sciences' Space Studies Board, which sponsored the Irvine workshop. As O'Keefe himself noted, the number of hits on the agency's Web site to access the latest findings from the Spirit rover far outnumbers those who logged on in the wake of the Columbia disaster. The White House, says one researcher, is missing the boat: "What excites people is Mars, Hubble, black holes—not the space station!"

Old hands can supply a litany of broken promises made to the science community. Apollo 18 and 19, devoted to intensive science studies, were canceled. Many of the shuttle's planned complement of scientific instruments, such as a solar telescope, never materialized, and innumerable space station facilities for biology, materials science, Earth observing, and astronomy were delayed or abandoned. Although science was touted as an important driver for NASA's major human space flight programs, other factors predominated. The Apollo program was the product of the Cold War, the space shuttle helped rescue a sagging aerospace industry, and the space station began as a race against the Soviet Union—only to become a tool for cooperation with post-Soviet Russia.

Administration officials warn researchers not to assume that past is prologue. "This vision has greater scientific relevance than past missions—and science will be more productive with it than in its absence," says Marburger. NASA space science chief Ed Weiler says the new approach will go far beyond Apollo's single-minded objective. "This is not a flags-and-footprint program," he says. "The moon is a stepping-stone, and scientists are excited about going to Mars." So is the president, he adds. At a January meeting, Weiler says, Bush asked "direct science questions," including one about martian carbonates.

Even so, science clearly will not be in the driver's seat for the new initiative. So should researchers go along for the ride anyway? "We have to avoid the sirens' call of money," says Yale University astronomer Meg Urry. She adds that researchers drawn into the effort should be careful not to sacrifice the quality of their work along the way. "We should always go for the best science; let's not do it just because there is money to be had." Others



A closer look? Scientists hope to return samples from the south pole of the moon, seen in the 1994 Clementine mission.

Asking for the Moon

The moon has been left in the dust in the stampede by U.S. researchers to study Venus, Mars, and the outer planets during the past 3 decades. The new White House vision for NASA promises to give lunar science its chance to shine, but NASA will have to play catch-up.

Although the American space agency has no approved lunar science mission, its European, Japanese, Indian, and Chinese counterparts are well on their way toward preparing spacecraft to explore the moon (*Science*, 2 May 2003, p. 724). A sample-return mission to the Aitken Basin at the lunar south pole will be part of a wider NASA competition now getting under way. Scientists can propose flights to Venus, Jupiter, and a comet as well as the lunar site. The winner, to be chosen next spring, must keep costs under $700 million and launch by 2010.

The president's 14 January announcement certainly gives a leg up to two proposals that would return lunar samples, NASA officials say. Each would touch down somewhere inside the basin, a vast feature some 2500 kilometers in diameter and 13 kilometers deep near the lunar south pole. A National Research Council decadal survey last year strongly backed a sample-return mission to the roughly 4-billion-year-old basin, which geologists believe to be the oldest in the solar system and an important source for data on its development (*Science*, 2 May 2003, p. 727). The region is also the most likely site for the lunar base that Bush wants to build after 2015. Two U.S. orbiters in the 1990s sparked a still-unresolved debate on how much water exists at the moon's poles and what form it takes. The presence of easily attained water would be a great help for lunar pioneers.

The chance to explore the moon, whether with humans or robots, excites researchers. The moon's surface may preserve meteorites from ancient Earth, Venus, or Mars, and its regolith—lunar soil—may hold clues to the charged particle environment in the solar system's early evolution. But NASA managers warn that even if the sample return is approved, that doesn't mean a U.S. flotilla of research-focused spacecraft will follow. Robotic flights to prepare for a lunar base would be paid for by NASA's technology office rather than out of the space science budget, says NASA space science chief Ed Weiler. "Out of 50 or 60 Discovery proposals, only three have been about the moon," he says regarding NASA's competitive program for robotic space missions. "The scientific community has not voted with its feet."

That comment infuriates some space scientists. "I'm taken aback," says Paul Spudis, a lunar geologist at the Applied Physics Laboratory in Laurel, Maryland. NASA "systematically rejected proposals to do lunar science for the last decade," he adds. "They locked us out." That attitude forced those interested in the moon to look elsewhere, says Spudis, who is proposing a sample-return mission. The other competitor is a team led by Michael Duke of the Colorado School of Mines in Golden.

In arguing for more attention to robotic lunar exploration, Spudis urges Weiler's office to consider history. Although the robotic Ranger and Surveyor spacecraft in the 1960s were designed primarily to test technology and ensure safe operation of humans on the lunar surface, he says they produced important science as well. "Those missions taught us a lot about how the moon works. So if we go back, there is scientific knowledge to be had."

–A.L.

take a more pragmatic view. "If we were given $1 billion to put a telescope on the moon," says Lester, "we'd be crazy not to."

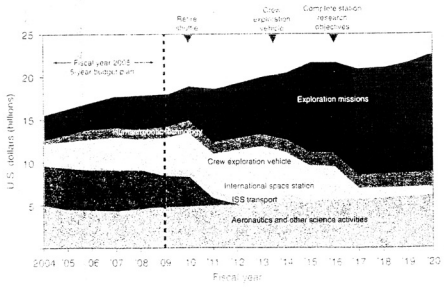
Most space scientists are awaiting NASA's 2005 budget request and its long-term plan for space science before casting their vote. Without a budget, says Lennard Fisk, an astronomer at the University of Michigan, Ann Arbor, who chaired the Irvine study and who once served as the agency's space science chief, "it is hard to know how excited to get."

In the meantime, astronomers are plenty agitated about the decision to cancel the Hubble servicing mission. They complain that NASA sprung the decision on the community without openly considering other options, such as moving the telescope to match the space station's orbit so it could be serviced safely. Congress is hearing their call. Senator Barbara Mikulski (D–MD), a protector of NASA's programs, is preparing to fight for another repair mission.

But even those concerned about Hubble's fate worry that such a battle would likely pit astronomers and opponents of the president's plan against planetary scientists and the Administration's supporters. Opposing the new exploration plan ultimately could prove dangerous for space science, warns Fisk. "We shouldn't lose sight of the fact that we need to provide human space flight with a valid mission," he says. "The entire space program is very unstable if half of it is in deep trouble."

In other words, before robots and astronauts can work together successfully in space, their advocates on Earth must learn to get along.

–ANDREW LAWLER



The blue and the gray. Some science programs would see a flat budget under the Bush plan for space exploration, which includes terminating the space shuttle in 2010. Other scientific efforts may be included in the exploration line, but details won't be released until next week.

Astronomers Ponder a Really Long-Range Vision for NASA

Scientists are deeply divided over what type of telescopes to build in space, where to put them, and what they should do—and that's before the politicians weigh in

They jokingly called it a *loya jirga*, after the contentious tribal council convened to choose a new Afghan government. The astronomers, earth scientists, and spy-satellite experts who convened last May in Boulder, Colorado, were indeed an ornery and territorial bunch. But the prospect of pooling their expertise to build space telescopes larger and more powerful than anything yet attempted was enticing enough to bring them together under one roof.

When the participants gather this May for *Loya Jirga II*, also hosted by NASA, there will be more on their minds than the details of competing technologies. The new White House exploration plan makes no mention of space-based telescopes, save for a reference to instruments to detect Earth-sized extrasolar planets. But retiring the shuttle and eventually abandoning the station to build a lunar base could have a radical effect on the size, design, and placement of a new generation of space telescopes—and on whether there will be any money to build them.

Researchers are divided on whether such instruments should be built by astronauts and robots or deployed by themselves. Location is also a thorny issue. Some favor the moon as the best location, whereas many others prefer free space; spymasters want to keep their assets disposable and in low Earth orbit. Still other scientists say the push for massive space observatories is wrong-headed, given advances in cheaper ground-based instruments. This spring, at the invitation of several federal agencies, the National Research Council (NRC) will convene a panel to examine the options for new space-based observatories.

On Earth, building a large mirror is a technical challenge limited only by money. But volume is also a problem for space-based telescopes, as the largest rockets can accommodate a payload only about 5 meters across. Anything bigger must be designed to unfold by itself or be assembled in space.

The James Webb Space Telescope (JWST), with a 6.5-meter aperture, is the first in what could become a series of segmented mirror instruments. When launched in 2011, it will automatically unfold its mirror in space, like petals of a flower. Pedro Rustan, who oversees advanced technology for the National Reconnaissance Office (NRO), envisions much lighter and more flexible structures that use nanomaterials and techniques to shrink mirror weight by eight- to tenfold. Working with NASA's Jet Propulsion Laboratory in Pasadena, California, the spy agency has already built a 0.2-meter telescope and is testing one twice as large. Rustan hopes to complete a 0.75-meter mirror in 2006 and a 3-meter version in 2008, with an eye toward a 10- to 12-meter mirror by 2012.

Peaceable kingdom? Drawing shows robots and astronauts working together to assemble a giant telescope in free space.

For NRO, servicing isn't an issue. Its budget is big enough to order a replacement when the existing instrument fails, eliminating the need for humans or even robots in space. "There will be a role for humans in space but not for a traditional role like Hubble servicing," Rustan argues. But for most scientists, sending up another telescope when the first one breaks "is not politically possible," says Roger Angel, an astronomer at the University of Arizona, Tucson. Instead, Angel and many other researchers prefer to rely on astronauts to assemble and maintain the instruments.

Where to site such an instrument is perhaps the most contentious issue of all. Angel favors the moon's poles, noting that "you have water that can be extracted and solar power." But increasingly, scientists say they prefer free space, and particularly the Lagrange points, where the gravity of two bodies—such as the sun and Earth—cancel each other out. (JWST will be parked at L-2, more than a million kilometers from Earth.) The points are stable, cold, and clean, and they provide a perfect view. "The moon is dusty; I don't see any advantage to it," says Riccardo Giacconi, an astronomer who heads Associated Universities Inc. (AUI) in Washington, D.C.

Servicing such distant observatories would be difficult and expensive but not impossible. Although JWST is designed to be disposable, NASA officials envision occasional sorties to future observatories at Lagrange points and a new launch vehicle to change out instruments and perform systems maintenance, much as was done with the Hubble Space Telescope in low Earth orbit.

Standing outside this debate over size and location are those skeptical of ever-larger-aperture instruments. "I just don't see it as necessary," says Anne Kinney, NASA's astronomy chief. She believes that ground-based telescopes fitted with adaptive optics, which can screen out the distortions of Earth's atmosphere, are much more cost-effective. Kinney says it makes more sense

Two views. Roger Angel (*left*) and Riccardo Giacconi disagree over the best location and design for a future generation of new telescopes.

FRONT (TOP) PHOTO BY ANDY S. KASTOPAUTS, JWC

to launch interferometers, which can create virtual mirrors that surpass any human designs.

Not quite, says Angel. Interferometers are great for searching out extrasolar planets, he notes, but cosmology relies upon scarce photons. Space is also the best place to observe at wavelengths absorbed by Earth's atmosphere, such as infrared.

The NRC report, written for NASA and the intelligence community, hopes to integrate these competing views into a comprehensive plan for space-based telescopes. The panel, not yet chosen, will build on last spring's Boulder meeting as well as a December workshop hosted by Johns Hopkins University and sponsored by AUI. Its recommendations, in turn, will be folded into the larger policy debate over implementing the president's vision for space exploration.

Bush's plan is sure to affect all aspects of future large space-based telescopes. Without access to a space station after 2016, assembling a telescope in orbit would be impractical. And the push for a lunar base might give moon advocates such as Angel a big boost. Most troubling for astronomers, however, is the fear that the cost of building a new launcher and setting up a base on the moon would squeeze out any revolutionary telescope project, no matter how enticing the technology or the science.

—ANDREW LAWLER

NASA Hopes Bigger Is Better for Planned Mission to Jupiter

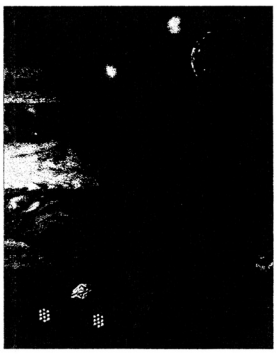
A nuclear propulsion system is expected to provide more power—and more angst—for a trip to Jupiter and its icy moons

For much of the past decade, NASA has operated according to the mantra "faster, cheaper, better." But like Detroit, the agency has recognized that there are limits to downsizing. Take its plans for the Jupiter Icy Moons Orbiter (JIMO), the biggest and costliest planetary probe in its history. This planetary sport-utility vehicle could travel for years in remote places, and it will test nuclear propulsion and power technologies that are seen as essential elements of the president's new space exploration plan.

But although scientists hope that the spacecraft will be a prototype for similarly giant probes to Saturn, Neptune, and the asteroids, other forces may keep it earthbound. A price tag approaching $10 billion could be a fiscal hot potato, and the specter of a radiation-spilling accident has already caught the attention of environmental groups. "If they can pull it off, this will be an intellectual boon of historic proportions," says Eugene Levy, an astronomer and provost at Rice University in Houston, Texas. But he and others, such as astrobiologist Bruce Jakosky of the University of Colorado, Boulder, are nervous. "The political future is uncertain, and my concern is that this could come to nothing," says Jakosky.

For scientists, the potential benefits far outweigh the risks. As now envisioned, JIMO would leave Earth around 2012, carrying a dozen instruments designed to conduct more than three dozen investigations and gather more than 12 dozen kinds of measurements. There may even be room for a small lander that would plummet to the surface of Europa, the moon believed to harbor an ocean—and, perhaps, ingredients for life—underneath its icy crust.

JIMO is the guinea pig for Prometheus, a nuclear technology program and the first major initiative of NASA Administrator Sean O'Keefe after arriving in December 2001. A former Navy secretary, O'Keefe is a fan of the naval reactor program and is eager to find a replacement for the chemical propulsion and solar power systems that have been the mainstay of NASA's human and robotic efforts since the 1960s. The space agency has occasionally used nuclear power, such as with the Mars Viking landers and planetary probes such as Saturn-bound Cassini, but O'Keefe argues that a higher scientific payoff requires vastly more powerful engines, power generators, and data-transmission components.



Prometheus Bound. Powered by nuclear reactors, the planned JIMO spacecraft is shown nearing the Jupiter system and its icy moons.

CHRIS BUNDA

Prometheus would develop advanced nuclear reactors—based on those used aboard Navy ships—to push the spacecraft to its destination as well as to operate onboard systems. Some previous NASA power systems used the decay of nuclear material to generate electricity, but not full reactors and not for propulsion. If the technology works, JIMO would free space scientists from the tyranny of hoarding watts and compressing data. All of Cassini's instruments together will consume 300 watts of power, return a few gigabits of data, and spend hours observing Saturn's moons closely. By contrast, JIMO would provide more than 10,000 watts of instrument power, some 500 gigabits of data, and months of observation time at each target, according to NASA documents. The spacecraft could orbit Europa for 2 months, then spend 4 months at Ganymede and another 4 months at Callisto.

Just a couple of years ago, a far more modest mission to Europa was on the verge of cancellation. So JIMO was a welcome and wholly unexpected surprise. "They replaced a $1 billion Europa mission with a $10 billion one!" jokes Jakosky.

Researchers last year worried that the experimental nature of the nuclear systems might make any scientific goals an afterthought. But a panel of NASA and outside scientists in December completed an aggressive science plan that the agency has embraced. "Science is really in the driver's seat in this mission," says NASA project scientist Curt Niebur. The panel concluded that the 600 kilograms' worth of instruments was too little and urged a minimum of 1500 kilograms. Saturn-bound Cassini, by contrast, includes 600 kilograms of scientific payload, most of which is devoted to the Huygens probe slated to fall into Saturn's moon Titan.

About a quarter of that larger science capacity on JIMO would be set aside for a Europa probe, with a lander that Niebur compares to "the size of a garbage can lid." In-

struments could include an astrobiology payload and a device to measure the depth of the ice pack covering the moon's surface. The density of that ice pack is the subject of a fierce controversy among planetary scientists, so the prospect of reaching Europa's surface by the next decade is an exciting one. "The risk is you send the wrong instrument or don't find a suitable place to land," says Jonathan Lunine, a planetary scientist at the University of Arizona, Tucson. Much will hinge on progress with the power and propulsion systems now getting under way. "You just can't do this mission any other way," says Ronald Greeley, a geologist at Arizona State University in Tempe who co-chaired the science definition team.

No glow. JIMO may face the same type of antinuclear protesters who greeted Cassini's launch in 1997.

But those systems will be both costly and controversial. When it was launched, Cassini drew protests and legal challenges from environmentalists who feared that an accident could disperse radioactivity in the atmosphere. O'Keefe insists NASA will deal head-on with the nuclear concerns. "In this past year we have specifically engaged all of the public interest groups—Greenpeace, Sierra Club, Friends of the Earth—everyone out there who has an issue or an interest in this," he says. "We're fresh-air Freddies here; what we are going to do is very transparent." NASA has even hired the Keystone Center, a Colorado-based public relations firm, to help its efforts.

Keystone officials did not return calls, but environmentalists are not impressed. "Keystone is not trying to address our concerns," says Bruce Gagnon. He directs the Global Network Against Weapons and Nuclear Power in Space in Brunswick, Maine, and was contacted by the company. "They are helping NASA put together a public relations strategy to circumvent those concerns." He adds that Prometheus would dramatically expand the amount of radioactive material being put into space and thereby increase the danger of a catastrophic launch failure. NASA, he warned, "is making a tragic mistake [with] trouble ahead for the scientific community."

And there is more than just Earth to worry about. NASA officials also are concerned about contaminating other parts of the solar system. "Because of radiation issues, we may have to make special provisions if the propulsion power system fails while in Europa orbit," according to NASA documents.

Such concerns are moot if the cost of JIMO and Prometheus prevents the project from reaching the launch pad. "We're talking about missions not less than $4 billion—and we haven't seen a commitment to sustain this," says Levy. But despite the risk, Lunine notes, "it's not as if NASA offered us a menu." That leaves planetary scientists with little choice but to hitch their fate to JIMO's uncertain star. And if it works, they should have plenty of legroom.

—ANDREW LAWLER

NASA's Plan for Station: From Lemon to Lemonade

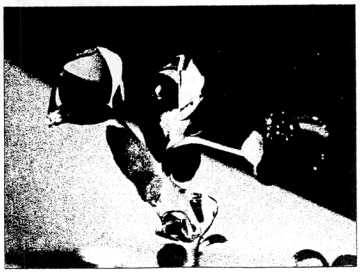
NASA halts plans for a research institute and takes yet another look at which science should and should not be done on the space station

Harvard physicist David Weitz studies the behavior of soft condensed matter through experiments aboard the international space station. But President George W. Bush's announcement this month that the orbiting lab will henceforth be devoted to science related to human missions to the moon and Mars has put him in research limbo. "If I take him at his word, then we're all out of business," says Weitz. "We should just pack up and go home."

Weitz is only the latest in a long line of scientists frustrated by their involvement with the space station. In the 1980s, the facility was touted as a place where industrial and academic researchers could harness the potential of zero gravity by developing new pharmaceuticals, conducting a spectrum of basic research, and examining the effects of space on plants, animals, and humans. Construction delays and cost overruns, however, have drastically shrunk that vision. The current unfinished facility has a staff of just two who can devote only a dozen hours a week to experiments. "The science you can do on the station is largely trivial," says Mary Jane Osborn, a biologist at the University of Connecticut Health Center in Farmington and a longtime NASA adviser on station research. "I feel both dispirited and mad."

NASA is betting that it can transform that anemic effort into a focused, viable, and credible effort. But, as with everything involving the space station, it will take time. Last week the agency postponed for at least a year its plans to set up an independent research institute to oversee station science. The delay will allow the agency to hear from a National Research Council (NRC) study, begun in response to the president's speech, on revamping the research program. Meanwhile, the NASA office that oversees biological and physical sciences may be reorganized, causing further delays.

But time may be running out. Bush called for a halt in U.S. station operations in 2016—far earlier than anticipated and just 6 years after completion. It is unclear how research will be done after retirement in 2010 of the shuttle fleet, which transports the large research racks that make science possible. In addition, a new crew exploration



Water torture. Plant experiments such as this one likely will be jettisoned in the next review of space station science.

ORIGINAL (1-PAGE BUSINESS) COPYRIGHT AAAS

vehicle (see below) won't be ready until 2014 or later. NASA also must consider its European, Japanese, Russian, and Canadian partners, all of whom have invested heavily in the facility. "No one should worry about the 2016 date now," advises David Black, president of the Universities Space Research Association (USRA) in Columbia, Maryland. "If the station is shown to be useful, there's no reason the station couldn't go on until 2020."

The new space station research program likely will have no room for materials science and fundamental physical and biological experiments, once seen as part of the station's unique contribution to cutting-edge science. The NRC panel will convene in March and hopes to deliver preliminary findings this fall and a final report within a year, says Mary Kicza, NASA chief of biological and physical sciences.

Kicza also last week abruptly halted a competition to set up the new institute, warning that the agency might drop the idea altogether. A 1999 NRC report strongly backed the concept, but managers at Houston's Johnson Space Center and Marshall Space Flight Center in Huntsville, Alabama, fought the idea of giving outside scientists any control over a space flight effort. Congress backed them up in 2000, forbidding any planning work, but the ban was lifted in 2002.

What remains, however, is a prohibition against overseeing engineering or integration work—a critical aspect of experiment preparation. That limitation is aggravated, say outside researchers, by Kicza's unwillingness to give the new institute the authority to choose most of the experiments and principal investigators. The institute, says one, "has become a threat" to NASA.

Not at all, responds NASA's Betsy Park, whose office manages the effort. NASA wants "a very strong research institute that can represent the whole community." Although the institute's authority would grow in time, she notes, "I don't think we or they are prepared for them to take over the whole thing."

NASA's skittishness frustrates those interested in bidding on the contract to operate the institute. Riccardo Giacconi, who led the Space Telescope Science Institute in Baltimore, Maryland, in its early years, notes that the telescope institute's power came only after "continuous bloodletting" with Goddard Space Flight Center in Greenbelt, Maryland, which operates the Hubble Space Telescope. "We earned their respect," he adds.

Giacconi now heads Associated Universities Inc. (AUI) in Washington, D.C., one of two organizations that intend to bid in the competition. "We need a more mature vision—and real scientists saying what makes sense," he says. "If we're not going to put [the station] out of its misery, then we need to decide what we can do." His colleague, AUI astronomer Ethan Schreier, warns that "we won't bid" if the institute is no more than a conduit to channel NASA money to researchers.

Researchers at the other likely competitor, USRA, agree that the institute needs greater authority. The current plan is "fundamentally a support-service contract," says Black. "We believe NASA needs to step away from running the research program and let the institute do the heavy lifting." In the aftermath of the president's speech and Kicza's decision to delay the institute, Black says he is more sure than ever that NASA must seek outside help.

In the meantime, Harvard's Weitz is waiting to hear from NASA about the status of his experiments. "I'm desperately worried," he says. "I may be closing down a third of my research group." But previous jobs in industry have taught him an important lesson, he says: "Things change, and you'd better adapt."

—ANDREW LAWLER

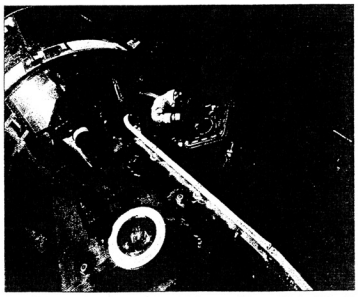
Versatility Is the Object for New Crew Vehicle

Can one vehicle really replace the shuttle, go to the moon, and take humans to Mars? NASA hopes industry comes up with the right answer

The president's announcement that NASA hopes to establish a permanent presence on the moon by 2020 has sent engineers and scientists scrambling to figure out how to get there. It will have been almost half a century since Eugene Cernan left his footprints on lunar soil in 1972, the last astronaut to do so, and NASA no longer has a spacecraft capable of taking up where Apollo left off. Indeed, because the president wants to retire the nation's current mode of transporting astronauts into low Earth orbit—the space shuttle fleet—in 2010, virtually all U.S. human exploration will be impossible unless NASA comes up with a safe and cost-effective vehicle that can replace the shuttle and also take payloads beyond Earth's orbit.

NASA's new vision will therefore be riding on efforts to build what the president called a crew exploration vehicle (CEV), to be ready to service the space station by 2014. Right now, nobody knows what it will look like, nor how it will take off and return to Earth. "They have to figure out a way to do this," says Roger Launius, a former NASA space historian now at the Smithsonian's National Air and Space Museum. "The complexity of any vehicle that goes beyond Earth orbit is raised immensely."

Since the last moon landings, NASA engineers have concentrated on missions to low Earth orbit: Skylab, Apollo-Soyuz, the space shuttle, Mir, and the international space station. Indeed, until the president announced the initiative, the big U.S. aerospace firms—Lockheed Martin and Boeing—were busy designing a replacement for the shuttle known as the orbital space plane (OSP) to conduct similar missions. But the requirements for an exploration vehicle that will reach the moon are very different from those of a crew-return or crew-transfer vehi-



Cosmic companions. Future moon missions could resemble Apollo's collection of a capsule, engine and life-support module, and lunar lander.

CREDIT: PICTURE NASA

cle for a space station.

The first difference is the preferred shape. A vehicle meant to pluck astronauts from the international space station—particularly in an emergency—should be able to maneuver upon reentry so that it can land in a suitable spot. If astronauts have to leave the station in a hurry, that maneuverability, something known as cross-range, can mean the difference between landing at a well-equipped U.S. airbase and the middle of Siberia. In contrast, a capsule like the ones used by the Mercury, Apollo, or Soyuz astronauts depends on a carefully timed reentry to land close to its target—a luxury that an injured astronaut might not have.

But the wings that gave the shuttle its distinctive shape and large cross-range aren't needed for a mission out of Earth orbit because they can't function in a vacuum or in a very thin atmosphere. "You don't need wings to go to Mars or the moon," says Michael Mott, vice president of Boeing NASA Systems. The current designs for the OSP included both planelike and capsulelike variants, anticipating the CEV's dual missions to ferry astronauts to the space station and take them out of Earth orbit. "I don't think that there's a serious change in direction for the CEV that NASA wants," says Mott.

A big difference between the OSP and the CEV, however, is the sheer amount of propellant that's needed to get the craft to its goal. A low-Earth-orbit spacecraft such as the Soyuz capsule need only carry enough fuel to knock itself out of orbit. A moon vehicle must have an extra engine and fuel to leave Earth's orbit and enter a moon-bound or Mars-bound trajectory, as well as enough propellant to break out of its new orbit and return to Earth.

Apollo engineers solved this problem by building an enormously powerful rocket. The Saturn V could lift about 120,000 tons to low Earth orbit, more than enough thrust to handle a large Apollo complex of spacecraft, extra engine, fuel, life support, and lunar lander. Thirty years of technological improvements will allow the CEV payload to be much lighter than the Apollo complex. "In wiring alone, you eliminate hundreds of pounds of wiring used in the Apollo mission," says Mott. Even so, NASA will need to think creatively: The launchers tapped for the OSP, the Atlas V and Delta IV medium, can't lift more than approximately 20 tons into orbit in their present configuration. As a result, the space plane, engine, and lander may have to be launched separately and then brought together in orbit, or NASA may even use existing Russian or European heavy launchers to get heavier components into orbit.

So far, nothing has been ruled out. "Nobody's said anything about the launch vehicle," says John Logsdon, a space expert at George Washington University in Washington, D.C. NASA Administrator Sean O'Keefe has stated that there are no plans to design a new launch vehicle from scratch, although he suggested that NASA will study how to get the required cargo into space with slight modifications of existing launchers. Current OSP designs show it sitting on top of a launcher, which would allow a small rocket to eject it if the launcher explodes on the pad.

The most striking difference between a moon mission and an orbital mission is the lander. Although the designs are very preliminary, there are hints that they will look like beefed-up Apollo landers, which were known as lunar excursion modules (LEMs). "Yeah, you see a lot of LEM-like designs," says Mott. "The physics hasn't changed, and the Mercury/Gemini/Apollo people got it right."

To satisfy those intractable physical laws, a CEV needs to be light, relatively simple, and able to link up with a lander, an engine, and a fuel source. It must also ferry astronauts on and off the space station under all conditions. This one-craft-does-all approach frightens Launius, who draws a parallel with a U.S. fighter-bomber intended to fulfill many roles for the Army, Navy, and Marines. First used in Vietnam, it was phased out in the 1980s. "The F-111 in the 1960s was supposed to do everything," he says, "but it couldn't do anything very well."

If history is any guide, NASA is likely to face similar pitfalls in building the CEV. Many consider the shuttle itself a failure; with a $400 million cost per launch, it never came close to fulfilling NASA's promise of cheap access to space. And several attempts to design a shuttle replacement or crew-rescue vehicle have gone awry, most notably the X-33. This experimental vehicle swallowed $1 billion before the program was cancelled a few years back. That level of performance, all agree, simply isn't good enough for NASA. —CHARLES SEIFE

From Bean Counter to Visionary: A Space Odyssey for NASA Chief

Two years after his arrival and 1 year after the Columbia tragedy, Sean O'Keefe is trying to take NASA back where it's been—and beyond

It wasn't too long ago that a senior Republican lawmaker blasted Sean O'Keefe's vision for NASA as "timid and anemic." Not anymore. Although many people are skeptical of the president's new direction for NASA, none is accusing the space agency's top administrator of being faint-hearted.

It is an astonishing transformation. As a Pentagon comptroller and second-in-command at the White House Office of Management and Budget, O'Keefe was known as a bean counter rather than a visionary. His arrival at NASA headquarters in December 2001 was greeted with dread by those who feared that his job was to keep expensive visions at bay.

Highlights. NASA Administrator Sean O'Keefe (left) rejoices with Cornell's Steve Squyres after the 3 January landing of the martian rover Spirit, which later developed communications problems.

CHRIS WALLY/SAN DIEGO UNION-TRIBUNE

Yet today the 48-year-old O'Keefe is at the helm of an ambitious effort to remake the U.S. space exploration program with the promise of billions of new dollars. What happened? "He's gone native," grouses one former Pentagon colleague, who complains that O'Keefe gradually was seduced by the glamour of the astronaut culture and swallowed up by the realities of directing a federal agency. Others say it was the Columbia disaster last February that forced O'Keefe to reckon with

the agency's future. But John Marburger, the president's science adviser, believes the rethinking began when O'Keefe was appointed to the job amid concerns about space station cost overruns. "That's when space policy began to change," he says.

In retrospect, the administrator's early push to develop nuclear power and propulsion systems, build a shuttle alternative, and lift the old taboo on discussing human missions beyond the space station were obvious clues to what lay ahead. In the wake of Columbia, O'Keefe surprised the White House by asking for a massive spending increase—on the order of $27 billion over 5 years—to speed up and expand work on these efforts, Administration officials say. The White House balked at the cost and insisted on a clear destination. O'Keefe came back this fall with plans to send humans to Mars; ultimately the president chose a lunar base as a more immediate goal that was less likely to cause sticker shock.

An ambitious and loyal Republican, O'Keefe is rumored to lust after a senior Pentagon post, a rumor he strenuously denies. Regardless, his political future may hinge on how well he runs the congressional gauntlet in coming months. He must convince skeptical lawmakers that his prescription for NASA will cure the ailing human space flight effort without hurting the healthier space and earth sciences. Gaining that support may prove tougher than getting face time with the president or vice president, a longtime patron. O'Keefe is respected on Capitol Hill, but he has a tendency to speak at length and say little. "He wouldn't know how to speak a straightforward sentence if you paid him," says one frustrated congressional aide.

O'Keefe spoke with *Science* just prior to the president's 14 January speech and, thus, declined to discuss details of the exploration plan. But he appeared relaxed and forthright in a wide-ranging discussion in his office overlooking the Potomac River and the Pentagon. His edited remarks on various topics follow. –ANDREW LAWLER

On the Mars Spirit rover:
How things have changed in a year! There is a very thin margin between great success and great failure, and I've seen both ends of it. On the Spirit landing, we didn't know how dense the atmosphere of Mars was. Had we [started the parachute firing sequence] a few seconds later, it would have crashed and might even have buried itself about 5 feet [1.5 meters] straight down. Holy cow—this could have been a disaster. And we might not have known why. That's the hairline difference between success and failure. It's razor thin. [Spirit's troubles as *Science* went to press painfully reinforce that notion.]

On the science behind exploration:
It will be a significant driver. The story of Spirit is both science and exploration. There's the theory and the tools. And then we're going to put the pedal to the metal and go explore, and figure out what is on the other side of that ridge. It's all about both. But … if you have to demonstrate every exploration goal with an exclusive scientific theoretical context, you are not going to capture the imagination—except for the community interested in that. The president has a very strong conviction that the combination of an exploration and a scientific agenda is a formidable effort and worthy of a noble nation.

Low point. NASA's Steve Altemus (right) shows O'Keefe wreckage from the space shuttle Columbia, which disintegrated 1 year ago.

On the critics of space station science:
In the last year and a half, we have energized the life sciences community in a way that hasn't been done before. They would not have looked at space flight [seriously] before. There's progress—but at the same time I'm not a Pollyanna. There is always going to be a parochialism of how my discipline is going to benefit.

On the cultural divide:
[Space flight and space science] are coming together; the cross-pollination is pretty extensive. We're going to pack up the folks who run [shuttle mission operations] at Johnson [Space Center in Houston] and send them to [the Jet Propulsion Laboratory in Pasadena, California] to sit through the run-up to the Opportunity landing. It is a terrible waste of capability to duplicate capabilities.

On what drives discovery:
Neil Tyson, the head of the Hayden Planetarium in New York City, has traced the [underpinnings of] seminal exploration achievements. First is national defense. Second is an economic advantage—such as going to the New World. Third is a national objective, such as the current Chinese motivation [for space flight]. And a fourth is human expansion based on knowledge and interest and desire. There are pitifully few of these achievements, but they do occur. And when they happen they are interesting, such as Chinese [ocean exploration] in the 14th century. Tyson argues that the Chinese [ultimately] made a determination that everything available elsewhere was of lesser value. They made that determination at their peril and to their detriment.

On George H. W. Bush's failed vision:
There are people who even in the last several months have asserted that all that is necessary is for the president to proclaim a vision and we're on our way. I said, "You think so?" If 1989 wasn't a demonstration of why that theory is wrong, then we didn't learn much! The articulation of a vision and a set of goals and aspirations is insufficient to really propel this [new initiative] anywhere. Our mantra all the way through has been: "Here's the direction, and here are the dollars to carry it out." Anything that requires a leap of faith, an invention, a suspension of the law of physics—any of those things—are disqualified. Those aren't visions, those are fantasies.

On completing the space station:
I think the scientific community thought [partial completion, dubbed core complete] was the goal, and that wasn't what was intended. We're looking at something on the order of half a dozen flights to reach core configuration once we return to flight and probably 25 thereafter to assembly complete.

On "going native":
You have to adapt to what the circumstances require. The history of the last 2 years is attention to cost consciousness. I think any objective observer would say NASA is profoundly and fundamentally different than it was 2 years ago. If that is going native, then it is a native instinct that wasn't present at this agency 2 years ago. The attitude when I walked in the door here by most senior folks was that something costs what it costs. I said, No, you better have a better idea than that—or else it'll cost nothing, because we won't bother doing it. If we are going to promulgate a policy it better be realistic, it better have goals and objectives, and we better have the capacity to really do it.

CREDIT: AP PHOTO/NASA

Adventure or Inquiry? Two Visions of Cosmic Destiny

THE NEW YORK TIMES, TUESDAY, FEBRUARY 3, 2004

ESSAY

By DENNIS OVERBYE

"The best marriage of human spaceflight and science." That is how Dr. John M. Grunsfeld, astronomer, astronaut and chief scientist of NASA, described the Hubble Space Telescope when he announced last month that the agency was canceling maintenance missions to the telescope, which has dazzled the world with crisp visions of the cosmos.

Like every marriage, this one has had its ups and downs, and it seems to be ending like "The War of the Roses." NASA officials moved as swiftly as assassins after President Bush ordered them to redirect resources toward the Moon and Mars. Without service calls from shuttle astronauts, the telescope is likely to die in orbit around 2007, making science the first casualty of the new era. Not an auspicious beginning.

NASA officials said it was a matter of safety, citing a recommendation of the Columbia Accident Investigation Board to send the shuttle only to the space station, unless tools are developed to inspect and repair fragile thermal tiles in flight.

The chairman of the accident board, Adm. Harold W. Gehman Jr., is now reviewing the decision, which outraged astronomers and others. "Bush's 'New Vision' is a sharp stick in the eye," said The New Yorker.

The shuttle and the space telescope were a marriage of convenience, the visions driving them composing a sort of yin-yang heartbeat inside NASA.

In the 1970's, astronomers, who had long dreamed of a telescope above the blurry atmosphere, had no choice but to build a telescope that could be launched and maintained from the coming space shuttle.

Proponents of the shuttle then argued that their winged spaceship would be a great boon to science, a claim that came true in 1993 when spacewalking astronauts corrected a flaw in Hubble's optics. Subsequent service calls by the shuttle have continued to hone and improve the telescope's capabilities.

As I pondered the imminent demise of this heavenly relationship, I was drawn to a pair of images, each emblematic in its own way of the era and of an attitude toward space and humanity's place in it.

One was taken from the shuttle Challenger 20 years ago this month. It shows Capt. Bruce C. McCandless floating alone in space above a blue Earth, like a human satellite or a lonely star child. He was testing a nitrogen-propelled backpack designed to allow astronauts to buzz around freely in space.

The other, taken by the Hubble in 1995 and nicknamed the Pillars of Creation, shows huge columns of primordial gas being boiled away to reveal nests of hot new stars being born in the Eagle nebula some 6,500 light-years from here. It is a vision of Genesis as a continuing project.

Together these pictures represent the poles of the space program, the dialectic that has driven debate about it since the rockets began to blast forth from Cape Canaveral half a century ago. One is the drama of human exploration: footprints and golf balls on the Moon, spacewalks, zero-gravity shenanigans, space sickness, claustrophobic dramas in a tin can as humans learn like fish crawling out of the sea to adapt to a new environment. This is the inspirational adventure that serves as the loss leader, loosening Congressional purses for other space activities.

The other is science, the endless inquiry into the brute divine processes through which we originated, performed by talented robots embodying all the ingenuity and persistence of their human designers and minders back on Earth, able to go where

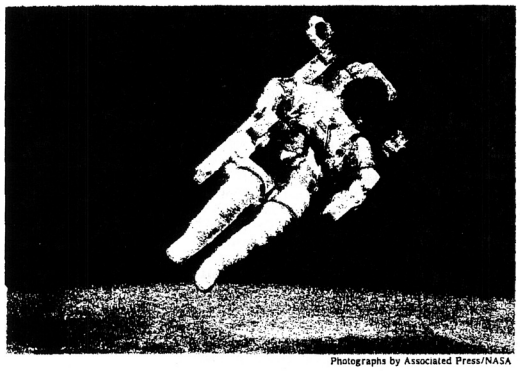
Pondering Einstein: Is the universe really comprehensible?

no human could tread, through radiation belts and galactic silence, to see what human vision could not even imagine until the holy pixels came beaming down from orbit.

In one of them, space has become an arena where humans pursue their destiny. And the elements of the universe take their meaning from their relation to people: Mars is a theater, a science-fiction one; the Moon is a way station, or an observatory. We own the universe, we mine it, settle it, play in it, build great floating edifices between the stars.

In the other, humankind is not present at all, except as some possibility eons in the future, a consequence of primordial processes virtually biblical in dimension. The universe owns *us*; we emerge inevitably or by luck from the chipping of DNA by cosmic rays, chemical currents in space, the bubbling of volcanic mud.

Captain McCandless's test flight came at an almost giddy moment in the history of the shuttle program.



Photographs by Associated Press/NASA

Two images symbolize a nation's attitude toward space and human flights: Capt. Bruce C. McCandless, above, tested a nitrogen-propelled backpack. Below, the Hubble Telescope detected the Pillars of Creation.

The Challenger and Columbia disasters were in the future. More and more people were flying in space and flying in a style to which they were not accustomed.

Astronauts loved the shuttle, and if you have ever spent time in a museum examining the cramped capsules that took humans to the Moon, it's not hard to see why. They had toilets and showers and hot food and the dignity of actually flying back to Earth, not being dropped like a sack of potatoes.

In the picture, Captain McCandless is above the Earth, sunlit in his white suit, tiny and fragile but triumphant all the same. Flying was fun.

Since then, most of the thrills in space have come from robots like the Wilkinson Microwave Anisotropy Probe that is mapping the remnants of the Big Bang, the rovers on Mars and of course Hubble, our clear-eyed sentry on creation.

President Bush has vowed to change that course. "Human beings are headed into the cosmos," he said last month, spinning visions of Moon bases and Mars explorers.

At one extreme, the Bushian vision of space is the universe as a thing to be exploited, as property. But another branch on this tree leads to the concept of stewardship, to a role of gods, as Stewart Brand put it in the Whole Earth Catalog long long ago, in charge of Spaceship Earth. In many ways this is no less arrogant than the idea of subdividing Mars before we have ever been there.

Surely it is folly to pretend that humans are in charge of their own evolution, let alone the rest of the universe. The asteroid or the killer virus could show up tomorrow. If we venture into the universe under the pretense of being owners, we are likely to get a rude awakening.

Science, of course, is not without its own sense of arrogance. We can figure out the answer; our minds are up to the challenge of understanding existence. Although why that should be so is the ultimate humbling mystery. "The most incomprehensible thing about the universe is that it is comprehensible," Einstein once said.

The tension between owning the universe and being owned by it is familiar to anyone who ever bought an old house. Whether it is our destiny to be Nietzschean overlords of this house of stars or temporary inhabitants is a mystery. Cosmologists admit they are baffled by the role of life in the cosmos. The universe and its laws, they have concluded, seem to be mysteriously intertwined. Life as We Know It seems to depend on a miraculous and improbable juggling of the numerical values of a few atomic constants.

Is life a lucky fluke? Are there zillions of different universes to choose from? What is life, anyway?

Having raised this issue, I have to say that I have no answer. Are we the lords of creation, or pond scum?

Not knowing is part of the fun, and I submit that it is our fate not to know. Such ambiguity is the source of richness of drama, art, life, perhaps even science. We are doomed — or privileged — to find our meaning in questions, facing as clear-eyed as the Hubble the prospect that answers will probably never be forthcoming.

In his book "The Life of the Cosmos," Dr. Lee Smolin, the physicist, lamented the lack of a final unified theory. "When a child asks, What is the world?" he wrote, "we literally have nothing to tell her."

Get used to it.