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NASA'S FUTURE SPACE MISSION

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED EIGHTH CONGRESS

SECOND SESSION

JANUARY 28, 2004

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED EIGHTH CONGRESS

SECOND SESSION

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NASA'S FUTURE SPACE MISSION

WEDNESDAY, JANUARY 28, 2004

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

The Committee met, pursuant to notice, at 9:30 a.m. in room SR–253, Russell Senate Office Building, Hon. John McCain, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. JOHN MCCAIN, U.S. SENATOR FROM ARIZONA

The CHAIRMAN. Good morning. On January 14, 2004, the President announced a new vision for the Nation's space exploration program, a vision that gives NASA a new focus and clear objectives, which the Columbia Accident Investigation Board concluded were sorely lacking. The man tasked with implementing this new vision is NASA Administrator Sean O'Keefe. I can think of few people more qualified to try to do this.

I welcome Administrator O'Keefe, and congratulate him on NASA's recent accomplishments, including the success of the robotic rovers on Mars, the collection of comet dust from *Comet Wild 2* that will be returned to Earth for analysis, and the receipt of new images of deep space from the Spitzer Space Telescope.

While he's more qualified than most any that I've ever known, particularly considering his experience as Deputy Director of the Office of Management and Budget, I'm very curious to hear how Administrator O'Keefe thinks we can implement the President's proposal with the very limited resources that have been proposed.

Two days ago, the Congressional Budget Office estimated that the deficit in Fiscal Year 2004 would reach $477 billion. It's been reported that the President's new proposal could cost between $170 billion and $600 billion. Needless to say, the $12 billion that the Administration has suggested to be spent over the next 5 years falls far, far short of what might be required to actually return to the Moon and reach for Mars and beyond.

We must acknowledge that space exploration, particularly manned exploration, is costly. We have existing obligations relating to the safe operation of the shuttles and the International Space Station. I think the American public is justifiably apprehensive about starting another major space initiative, for fear that they will learn later that it will require far more sacrifice or taxpayer dollars than originally discussed or estimated.

As I mentioned during Administrator O'Keefe's confirmation hearing, a vision without a strategy is just an illusion. The country

is not interested in, nor can it afford, another space illusion. Therefore, I look forward to hearing from Administration O'Keefe, along with our other witnesses today, about the strategy that they believe will make the Administration's vision a reality.

Senator Wyden?

STATEMENT OF HON. RON WYDEN,
U.S. SENATOR FROM OREGON

Senator WYDEN. Thank you very much, Mr. Chairman.

I want to welcome the Administrator, as well, today and thank him for his service.

I'd just like to make two points, very briefly, Mr. Chairman. The last time the Administrator was here, I asked that the agency initiate a cost-benefit analysis to look at the matter of manned spaceflight. And, if anything, the developments of the last few weeks have, I think, increased the need for just such an analysis. If anything, if you look at the plans that have been announced recently by the President, it is clear that they focus even more extensively on human spaceflight. And so, Mr. Administrator, the first question that I'll ask you is to get into this question, the cost effectiveness of manned spaceflight. Because it's very clear that, given the ambitions of the President and the budgetary realities, it's important that we get a sharper and more focused sense of what can be done through manned spaceflight and what can be done through other operations.

The other area that I'm going to ask you about, Mr. Administrator, is, I have to tell you, I was extremely disappointed to learn that the agency collected personal data on more than ten million Northwest Airline passengers in 2001, and retained that data for years, without informing the passengers that the agency had this personal information. In 2003, Northwest had more than 500,000 passengers travel in and out of Portland International Airport, so I can only imagine how many of my constituents had their personal information simply handed over to the agency.

I have legislation right now, the Citizens Protection and Federal Data bases Act, which aims to correct the careless collection and dissemination of private personal information by Federal agencies. My understanding is that the agency has now asked Northwest to hand over the information. The airline has agreed. But I'd like to know, prior to that, what steps were taken to protect the more than ten million individuals that were caught up in that data base.

So those two areas, I'll be exploring with you specifically this morning.

Mr. Chairman, again, I thank you for the hearing. And this is an important time for the agency. Mr. O'Keefe has always been extremely responsive to our inquiries, and I look forward to discussing these issues with him this morning.

The CHAIRMAN. Thank you, Senator Wyden.

I'd like to remind my colleagues that we have votes starting at 11:40, and we have another panel, as well as questions for Administrator O'Keefe.

Senator Brownback?

STATEMENT OF HON. SAM BROWNBACK,
U.S. SENATOR FROM KANSAS

Senator BROWNBACK. Thanks, Mr. Chairman, and thanks for holding the hearing.

And congratulations, Mr. Administrator. We've had you up here for a number of hearings over the past year, and they haven't generally been a very joyous occasion. I just came from the office, and they're shooting back pictures from your second rover that's on Mars now, and it's just amazing photography. Going two for two in a place that's difficult to get one to land is an extraordinary feat, so congratulations to you and the agency.

And I want to thank you for listening to Congress, particularly Members in the Senate, about articulating a vision and getting us out of low-space orbit and a manned program. A number of us have met with you over a period of time. And I remember a particular meeting, with the Vice President, where a number of us were saying we need a vision, and we need it articulated by the Administration. And you've put that forward, and I appreciate you laying that out. I think it's a bold vision, I think it's aggressive.

What I also like is your pay-for strategy that you put—where it's basically redirecting current funds with some additional, but not a great deal of additional, funds. I think it does both break us out of low-space orbit, where we've been stuck for the last 20-plus years in the manned program, and sets a bold, yet achievable, vision. And it causes us, as a society, to lean forward and lean into it and not say, we're going to wait on the Europeans to go to the Moon, or, we're going to wait on the Chinese to go to the Moon, we're going to let somebody else lead in this, because it's too dangerous, it's too expensive. No, it's none of that.

You're saying, we're going to lead forth. And if others want to join us, we want them there. But that's the right way, and that's the place for this country to be. And it's that kind of vision that encourages a 13-year-old in Pittsburg, Kansas, to dream great dreams important to the future of this society. So I'm glad you've put it forward.

I want to ask you some specific questions about making sure we stay on target with this one, and not sliding off like we have sometimes in the past when these have been articulated.

Welcome back.

Mr. O'KEEFE. Thank you, sir.

The CHAIRMAN. Senator Nelson?

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

Senator NELSON. Senator Breaux just said he really thinks that rover is wandering around in the Mohave Desert. Like those who said we never went to the Moon.

[Laughter.]

Senator NELSON. Mr. Chairman, you can't do spaceflight on the cheap. And I just don't think that a billion-dollar increase over 5 years—that's $200 million a year—is going to do it. And I would love for you to explain, on the reprogramming of the $11 billion over that 5 years, how you can do that.

I think my other concern is that I would not like to see repeated the period of time between 1975 and 1981, when we were down and not flying with humans. When *Apollo-Soyuz* last flew, and the space shuttle was supposed to fly 3 years later, it wasn't until 1981, a total of 6 years that we were down. And my concern, in what you've outlined and what the President outlined in the speech over at NASA Headquarters, is that you phase out the space shuttle by 2010, and then if we don't fly this new vehicle until four, five, 6 years later, that means that our only human access to space is that we've got to rely on Russian rockets and European rockets. I don't think that's good for the country. So rather than having a hiatus, I would love to have you comment as to how we might have an overlap, where we would keep the space shuttle flying until such time as the other vehicle is already tested and ready to fly.

And then the other thing that I would say, Mr. Chairman, is, a project of this magnitude, it can only be led by the President or the Vice President. And I was one of the cheerleaders that was there when the President made his announcement. But 6 days later, when he had the opportunity to put some juice behind it, and the prestige of his office, he did not mention it in the State of the Union speech. And so if we do not have the full weight of the President behind it, I'm afraid it's going to fizzle, and it's going to make it very difficult for us, up here, to get the votes to sustain a program such as this.

And thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Again, I would request that my colleagues keep your opening statements brief, as we have another panel, and votes beginning at 11:40, as I understand.

Senator Hutchison?

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

Senator HUTCHISON. Thank you, Mr. Chairman, for holding this hearing.

I just want to say thank you, Administrator O'Keefe. I have been one that has pressed you about a vision for NASA since you took office, from the day you had your nomination hearing to become the NASA Administrator, I have felt that we have drifted since our early successes in space. Our successes in space cannot be refuted. We dominate the skies, we have received tremendous benefits for our defense and our national security, and the benefits for quality of life and the industries that have been spurred are unquestionable.

I love the vision of the President. Many of us encouraged him, the Vice President, and yourself to do. I do think that follow-through and follow-up is going to be important.

In closing, the only thing that I would say, because I want to be brief, and I certainly want to look at the details of the budget. We want to make sure we do this right, not only for safety, but for making sure that we don't waste the effort and the money. So I hope that we will go forward, realistically have a budget that will do the job right. I will be very anxious to see where you're going to take money from, $11 billion will be taken away from other pro-

grams, because, of course, I hope that we would make sure that the programs that are going to support man on the Moon, and getting there, that the programs themselves would be kept and solidified as we are making this major commitment.

So I thank you for forcing the vision. Now let's work together to implement that vision in the right way.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Breaux?

STATEMENT OF HON. JOHN B. BREAUX,
U.S. SENATOR FROM LOUISIANA

Senator BREAUX. Would you like me to be brief, Mr. Chairman?

[Laughter.]

Senator HUTCHISON. He only says that before I speak, Mr. Breaux.

[Laughter.]

Senator BREAUX. Well, thank you very much, and thank you for having the hearing.

I think that it's an indication of the interest this Committee has and the Senate has in the subject matter that Mr. O'Keefe brings to the table that we have a good turnout of Members, and it shows a real interest in the program.

I'm concerned, Administrator O'Keefe, about what I would term the uncertainty of where we are. And I think you're hearing that from many of the opening comments.

The last time you and I visited, we were talking about an OSP, which was the orbital space plane. Since that time, I understand that that is no longer there; we're now talking about the CEV, or the crew exploration vehicle. So we've made some changes in direction. We're now talking about going back to the Moon. We've already been there, but we're going back. And we now have two unmanned vehicles on the planet Mars. We're talking about reprogramming $11 billion. There's a lot of uncertainty as what's going to be cut and where the money's going to come from to raise the necessary funds to do these very adventurous programs.

I supported, very strongly, the concept of increasing and expanding space exploration. I think we, down on Earth, get a great deal of benefit from those activities, and they're extremely important. But what I think we're looking for today is a clearer path as to how we get from here to there. There's been a lot of changes, a lot of personnel changes, a lot of project changes. And I think what Congress wants to know, that we, indeed, not only are on the right path to get to the Mars, but we're, indeed—here on Earth, we are on the right path to be able to accomplish those goals. And that's what we're looking for.

Thank you.

The CHAIRMAN. Senator Allen?

STATEMENT OF HON. GEORGE ALLEN,
U.S. SENATOR FROM VIRGINIA

Senator ALLEN. Thank you, Mr. Chairman.

And thank you, Administrator O'Keefe, for being here. It's always a pleasure to have you here, and I commend you and your

entire team for the historic achievements on the Mars exploration. It's fascinating to me and to all here on Earth.

On this day in history, January 28, 1986, it may have been mentioned, about an hour or so from now, we had the tragic explosion of the *Challenger*. And NASA is beginning more journeys. Obviously, the *Columbia* tragedy is one that propels you all. And this has lifted the spirits of everyone, the Mars exploration.

The President has proposed to go forward with his space exploration program, which is a very unique national asset. I think after listening to Senators Breaux and Hutchison and others, the key to the strategic plan is that it is executed with proper preparation, with constraints on spending, making sure that there's not just a logic, but obviously your essential leadership is needed in the first, let's say, 5 years of this new strategic plan.

I do think space exploration makes good sense for us in a variety of ways—in knowledge, in innovation, in discovery.

I want to make sure—and you've heard me say this before, Mr. Chairman, and this whole Committee—that you remember the aeronautics aspect of NASA. As you move forward, I want to be assured that this new initiative does not have a negative impact on the aeronautics research and development budget.

The vision, as I understand it, calls for a billion-dollar increase over the next 5 years. It also calls for reprogramming of the existing $11 billion within NASA to cover these costs. I do see, from this budget here, though, the strategy based on long-term affordability, and I would like to see the numbers behind it. But it appears that, for at least the next three, maybe four, years, the aeronautics and other science activities would actually decrease until FY, maybe, 2008.

Now, aeronautical advancements are absolutely essential for our national security. You see it in every military action. We saw it in Iraq, on how important that is. The research and development budgets have been cut from $920 million, in 1998, to just over $500 million, in 2003. At the same time, our friends in Europe are, of course, developing a long-term plan to achieve global leadership in civil aviation. So for the sake of civil aviation, also our national security, I want to make sure, as you go forward with this new strategic plan, as we go through the details of it, that we do not forget aeronautics, which are so essential to our country through our security. I look forward to your remarks.

And I'd like to put my statement into the record, Mr. Chairman.

Thank you.

The CHAIRMAN. Without objection.

[The prepared statement of Senator Allen follows:]

PREPARED STATEMENT OF HON. GEORGE ALLEN, U.S. SENATOR FROM VIRGINIA

Thank you Mr. Chairman.

Administrator O'Keefe, I want to thank you for appearing before the Committee today and congratulate you and the rest of the men and women at NASA for the recent historic achievements in the Mars exploration mission. The work taking place on both rover missions—"Spirit" and "Opportunity"—is truly fascinating.

As NASA begins to journey forward after the *Columbia* tragedy, I believe a new focus and vision on Space Exploration is a salutary goal for the *Columbia* crew and their legacy.

Everyone can agree that NASA's Space Exploration program is a unique and treasured national asset. It is far and away one of the best examples of American

ingenuity and innovation holding tremendous promise for future generations. The President's Exploration Vision outlined earlier this month—I believe—is a step in the right direction as virtually every aspect of NASA depends on the success of the Space Flight Program.

As it has in the past, I am confident that the success of the Space program will continue to expand our knowledge base, revolutionize our understanding of the universe and produce technological advances that benefit all mankind.

I generally view the space program as a means to a greater end. That end being the research, innovation, exploration, and the discovery that occurs in space. As we examine NASA and the President's new vision we ought to ensure the Exploration Vision includes a continued focus on aeronautic related research.

I am concerned as NASA moves forward implementing this new initiative that it may have a negative impact on NASA's aeronautics research and development budget. I understand the Vision calls for a $1 billion increase over 5 years for NASA's overall budget; however it also calls for $11 billion to be "reprogrammed" within NASA to cover these costs.

In addition, I see from the projected budget provided by NASA that aeronautics and other science related funding will be decreasing over the next five years.

The aeronautics industry contributes $343 billion to our economy and employs 4.2 million Americans. Yet NASA's aeronautics R&D program has steadily declined in the last decade from $920 million in 1998 to just over $500 million in 2003. During this time our European friends are developing a long-term plan to achieve global leadership in civil aviation.

I have previously raised similar concerns about aeronautics and using other advancements in technology (specifically in the areas of robotics) that could potentially minimize risks associated with Human Space flight and overall spending.

I do not disagree that we must strive towards new discoveries and explore our galaxy, but we should pay due attention and consideration to the technology and innovation that provides for our unrivaled military and civil aviation success.

Administrator O'Keefe, I appreciate you appearance before the Committee today and I am hopeful you can comment on NASA's plans to stay focused on aeronautics related R&D and how that may be incorporated into the new Exploration Vision.

Thank you Mr. Chairman. I look forward to the testimony.

The CHAIRMAN. Senator Lautenberg?

Congratulations, on behalf of all of us, on your recent marriage.

STATEMENT OF HON. FRANK R. LAUTENBERG, U.S. SENATOR FROM NEW JERSEY

Senator LAUTENBERG. Hear, hear. I've been to the Moon.

[Laughter.]

Senator LAUTENBERG. Thank you very much, Mr. Chairman. And thanks for the good wishes. I hope that my marriage lasts as long as this trip is going to take to get us to Mars.

[Laughter.]

Senator LAUTENBERG. I hope that I last that long.

[Laughter.]

Senator LAUTENBERG. Mr. Chairman, thank you for holding this hearing this morning. And I'll try to be brief. I'd ask the consent that my full statement be included in the record.

The CHAIRMAN. Without objection.

Senator LAUTENBERG. I thank you.

[The prepared statement of Senator Lautenberg follows:]

PREPARED STATEMENT OF HON. FRANK R. LAUTENBERG, U.S. SENATOR FROM NEW JERSEY

Mr. Chairman,

Thank you for holding this hearing on President Bush's proposal to reinvigorate the space program by sending astronauts to the Moon and to Mars.

The administration estimates that such a mission would cost 170 billion dollars. The proposal is so sketchy on details, I doubt that estimate is anywhere near accurate.

But even if it is, and we go to Mars, we better hope there's gold there to pay for the trip; we're not going to find the money to pay for it here. Not when this administration's tax cuts have helped turn a ten-year surplus projected at 5.6 trillion dollars into a 3.5 trillion dollar deficit—right as the first cohort of Baby Boomers gets ready to retire.

The President has a habit of announcing grandiose programs and reaping the positive publicity but then not following through with the necessary funding. Maybe we should call the mission to Mars *"No Planet Left Behind."*

I wonder if the President wants to send former Treasury Secretary Paul O'Neill on the manned mission to Mars. I say this because one of the very real obstacles we face is that while it may be feasible to get people to Mars, we don't have the propulsion technology to bring them back.

I hate to sound completely cynical but it's hard to avoid thinking that announcing this "mission" is nothing more than a ploy to divert the public's attention away from the administration's failed economic policies.

Last month, the economy created 1,000 jobs. At that rate, it would take nearly 249 years just to get back the private sector jobs that have disappeared under President Bush's "stewardship" of the economy. Meanwhile, 43 million Americans don't have health insurance.

Having said all that, I am not unalterably opposed to all space exploration. I am as excited as the next person about the images and data we are receiving from our Rovers "Spirit' and "Opportunity," which underscores the point I would like to make: there is much we can continue to learn from the unmanned exploration of space.

We don't need to incur the extraordinary risks and costs associated with manned exploration of space to learn more about the universe and our place in it.

Whatever we decide to do, we can't be for it and for tax cuts, too—not on the heels of the Space Shuttle *Columbia* accident.

When taxes are cut too much, and revenue streams dry up, and budget deficits spiral out of control—which is what's happening now—the government becomes constrained in what it can do. Frankly, the President's proposal strikes me as frivolous at best.

I look forward to hearing from our witnesses about how we could possible reconcile our current budget woes with the astronomical cost—pardon the pun—of sending humans back to the Moon and then on to Mars.

Thank you, Mr. Chairman.

Senator LAUTENBERG. There's an estimate out there, by the Administration, that this mission might cost $170 billion. And the talk about a human presence on Mars, I find interesting; but, frankly, I also find it to be challenging, and challenging because we're seeing so much by the way of technological development that surprises us all. And talking to some friends in medicine, talking about how much more accurate, how much more reliable it is do brain surgery with instruments going into the head and the scalp and—I have that interest because I had a ski accident last year, and thank goodness the guy didn't—wasn't nervous, who did this thing—I don't think, anyway; you'll have to make that judgment.

[Laughter.]

Senator LAUTENBERG. But the fact of the matter is that we've found that areas around the heart are better tended to electronically and mechanically than human intervention, and I really wonder, Mr. O'Keefe—and I salute you and all the people there who tried so hard. And I know the heartbreak that the agency's been through, and that they have done the best that they could. And perhaps we could even do better, was it financed at a higher level. But right now we're looking at a $5.6 trillion reduction in surplus into a $3.5 trillion deficit, and on the eve of the baby-boomers getting ready to retire. And I wonder what the President's mission is

here, when we talk about the kind of expense that it would take to move people back up into space, to get them to Mars, a stop along the way on the Moon, and when there's so much by way of current domestic need. Last month, the economy created a thousand jobs. At that rate, it would take nearly 250 years just to get back to the private sector job level that we had before. Forty-three million Americans without health insurance.

So I'm not unalterably opposed to space exploration. I'm excited as the next person about the images that we're getting back from the Moon. And I salute, again, the agency for the work that it did with the rovers up there.

But the question is, can we afford to do this, and is it really necessary? I don't know whether the question about whether a human presence is really essential to get the information we want, or whether it can be done electronically and scientifically.

So, Mr. Chairman, I look forward to hearing, from our witnesses, how we can possibly reconcile our current budget woes with the costs that it's going to require of sending humans back to the Moon and then on to Mars. And I thank you, Mr. Chairman.

And I thank you, Mr. O'Keefe, for being here and the work that you do.

The CHAIRMAN. Thank you, sir.

Senator Sununu?

STATEMENT OF HON. JOHN E. SUNUNU, U.S. SENATOR FROM NEW HAMPSHIRE

Senator SUNUNU. Thank you, Mr. Chairman.

Welcome, Administrator O'Keefe. You've had a lot of quality face time on TV lately. You and your staff are to be congratulated. And I certainly join others in wishing you luck in the coming weeks for the science expeditions on Mars.

Thank you.

The CHAIRMAN. Thank you.

The CHAIRMAN. Senator Stevens?

Senator STEVENS. I have no formal statement. I'm glad to see our friend, Sean O'Keefe here. We swore in, the other day, the new comptroller of NASA, and we discussed the President's program at that time, Mr. Chairman.

The CHAIRMAN. Thank you.

Welcome, Mr. O'Keefe.

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

Mr. O'KEEFE. Mr. Chairman, thank you very much. I appreciate the opportunity to be here. I'll submit the statement, for the record, and quickly summarize. As I understand, the Committee has indulged to permit a showing of a short video here.

Excuse me, is my microphone not on?

The CHAIRMAN. A little closer, I think.

Mr. O'KEEFE. A little closer? Does that work?

The CHAIRMAN. That's better.

Mr. O'KEEFE. Excuse me.

If I could, I'll submit the statement for the record, briefly summarize.

The CHAIRMAN. Without objection.

Mr. O'KEEFE. And I understand the Committee's indulgence is to have a video here, we've got available here in just a moment.

First and foremost, the Columbia Accident Investigation Board has, as all the Members recall, very specifically called out the requirement, that there be established a statement and a clear understanding of a vision, a strategy and a direction for the space exploration endeavor. And that was one of the very fundamental aspects of their findings of what they believed was not only necessary, but also its absence in the recent past as being a fundamental factor that led to the conditions under which the accident occurred—that, having been produced on August 26. A few months before that, we began an interagency process that we have discussed at this Committee on several occasions, as well as others around the Congress; have requested the input, and have received it from several Members; and very much appreciate the time and effort and energy that has been taken to help shape this objective. The administrative work of pulling together all those internal interagency efforts was conducted over the course of that time, and the President announced, on January 14, the vision that has been called for by the Accident Investigation Board, by several Members of Congress, by any other external commentary that could be offered.

The vision forms the basis of a new space exploration policy. It is a Presidential directive. It is established as the direction that vitiates all prior effort that would have governed the space policy direction. "A Renewed Spirit of Discovery" is its title.

The policy is the product, again, of that extensive interagency process, as well as solicitation and view of various Members and others in the community. The fundamental goals of the exploration policy is to advance U.S. scientific and economic interest through a robust space exploration program; to implement and sustain an affordable human and robotic program—it is a very carefully crafted combination of both; a return to the Moon by the end of the next decade, in preparation for human exploration beyond; promotion of international and commercial participation and exploration to further that scientific, security, and economic interest, as well.

The fundamental elements of that, that the President described in great detail on January 14, and I will quickly summarize here, is, first and foremost, the direction from him to return the space shuttle to flight. Our objectives are to follow the recommendations of the Accident Investigation Board—we have embraced that report; we will comply with it in its entirety—and assure that, when we return to flight, we have determined that we are fit to fly in accordance with those recommendations. And so as soon as practical, that event will occur.

The purpose of that return to flight and the necessity to continue operating the space shuttle for the foreseeable future in this decade is to complete the International Space Station. It is the only research platform for the purpose of fully understanding the effects on long-duration human spaceflight. And so understanding what those physiological and human effects are, and how to conquer them properly for future exploration objectives that are called for in the President's vision and strategy statement, are a necessity

that we will continue to perform on the International Space Station.

We've agreed, with our other 15 partners from around the globe, and have consulted with them extensively, on the means by which we will complete that assembly sequence over the course of the next several years, with the objective of retiring the shuttle after the assembly of the station is complete, at the end of the decade.

Next is a movement and a direction very specifically toward a crew exploration vehicle. And, again—Senator Breaux referred specifically to this point—this is an objective of building on the capacity of the orbital space plane and the capabilities that we investigated over the course of the past year, and developing, then, instead, a capability that takes it the next step beyond that, beyond low-Earth orbit; whereas, the orbital space plane was specifically an objective of taxi between here and station, not designed to go beyond that objective. So, in that context, what the President's called for is an exploration vehicle that can progress beyond low-Earth orbit, return to the Moon, Mars, and beyond, for the purpose of those objectives.

Under the name and title of "Project Constellation," we will proceed ahead with the development of that exploration vehicle, provide crew transport for exploration missions beyond low-Earth orbit.

In addition, lunar exploration objectives are underway. We'll be pursuing, in a robotic form for the balance of this decade, to begin those efforts; and, again, with the objective of looking toward the middle of the next decade for a return to the Moon, as well.

Exploration of Mars, I believe we've seen that illustrated in grand fashion here in recent days; and so to build and develop more on the basis of that particular success, and to inform the investigation necessary, based on the science, to pursue those destinations in the future, is what he has called for in his vision statement, as well.

To help derive the view of what other efforts are necessary to implement this strategy—because, again, this was an interagency process of public servants within the Administration who developed the options for the President's consideration—he chose the strategy he announced on January 14, but it was primarily derived from the work of this interagency process, internal to the Administration, in addition to the inputs that we've received from Members of Congress and elsewhere.

But to formalize that a bit more and fully understand what other implementation strategies we may pursue, other factors, from a more broader, external basis, the President asked former Secretary of the Air Force, Pete Aldridge, to chair a Commission to look at implementation strategies of this vision. This is a specific set of objectives that is articulated in the President's directive. In turn, how do we go about implementing it best? And his task, over the course of the next 4 months, will be to gather those thoughts from a broader external set of inputs in order to factor, as we move ahead with the President's program—it will be announced and laid out on February 3, as part of the President's budget submission—the approaches that we need to take in the years ahead in order to achieve this particular objective.

In the immediate time after the President's speech, the next day, we announced a reorganization of the agency to establish an Exploration Systems Enterprise to look at the task of accomplishing the President's objectives as a system of systems. It is not a singular program, it is not a singular set of objectives; it is a range of capabilities that can be employed, informed by what we receive, I think, from the continuing efforts of the various program engagements that we'll see in the President's budget, as well as that which is offered to us by this external panel, in order to move ahead on a broader range. And, as a consequence, the Exploration Systems Enterprise will have the primary responsibility for the development of the crew exploration vehicle, under the term Project Constellation, and, in turn, also coordinate the Project Prometheus efforts for power generation and propulsion capabilities beyond low-Earth orbit.

We've also established an aeronautics enterprise, very specifically titled as "An Aeronautics Enterprise," with the objective of assuring that it not get lost in the equation, because it's an essential piece of what we do and how we're organized. And so, as a consequence, there is a very clear focus on that objective, as well.

The vision, as you'll see, I think, when the President's budget comes out next week—and I would hope that Members would examine that budget before making determinations of its overall efficacy or utility; it will be out next week, and the full detail will be available—is, in our judgment, an affordable effort, both short term, as well as long term. The request, to be released on the 2nd, is fiscally responsible, it fits in the context of the overall statement the President has made on what drove his budget considerations for the 2005 submission, to achieve half of the deficit projection within the next 5 years, as well as to maintain spending in the coming year to less than 4 percent. We are within that amount, and, over the course of the 5 years, are also projected, within the overall budget projection, to be in that context, as well. And more on that, again, after next week, as you see the detail that's relayed very specifically.

As an immediate example of the illustration of how this strategy will be carried out, I would submit that the Spirit and Opportunity experiences we've had here in the last 3 weeks are an illustration of how that robotic capability can be a precursor to future exploration agenda. And it is about exploration. That is the primary focus of what the President's guidance and directive has stated to us, in terms of what the focus needs to be and its context needs to be considered in.

And with that, Mr. Chairman, I'd like to, if you would indulge, play a short video that gives you a sense of the—a combination of things. This is an animation of what occurs as the Mars exploration rovers are approaching the planet, as well as the splicing in of real scenes of the landing sequence, as well as some images from both the Spirit and Opportunity landing sites that were established.

And, if you will, Mr. Chairman, I'll play that at this time.

[Video presentation.]

Mr. O'KEEFE. Mr. Chairman, these are precisely the kinds of precursor robotic missions we will continue with a lot in the future in

order to advance, before the human exploration endeavor is engaged in. But it is an integral interrelated kind of activity.

We are, as Senator Allen referred to, extremely mindful of the risks that are attendant to this exploration endeavor. Today is the 18th anniversary of the loss of *Challenger*. And, too, we'll announce, this afternoon, the naming of the site that Opportunity landed at as the Challenger Memorial Station.

Yesterday, the anniversary of the *Apollo 1* fire, mindful, again, of the risks of exploration that we continue to pursue, the plains and the number of ridge lines at the Spirit site, the three highest peaks are named for Grissom, Chaffee, and White, those who we lost on that fateful day.

And as we continue on, through this very, very difficult weekend ahead of us, to recognize and to commemorate the lives, and celebrate the lives, of seven extraordinary people aboard *Columbia,* I think more will be recognized on precisely their contributions, as well. But that is part of what helped motivate this change in the vision. The Columbia Accident Investigation Board's call for exactly this kind of a statement, I think, is the legacy of *Columbia* and those who followed—or those who preceded, and we intend to honor that legacy with the best of our ability.

Thank you, Mr. Chairman.

[The prepared statement of Administrator O'Keefe follows:]

PREPARED STATEMENT OF HON. SEAN O'KEEFE, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Mr. Chairman and Members of the Committee, thank you for this opportunity to appear today to discuss the President's vision for U.S. Space Exploration and NASA's plans for implementing this vision. On January 14, 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," a copy of which is appended to this testimony. This policy is the product of months of extensive and careful deliberations. 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 their ideas for the future of the space program. These deliberations also formed the basis for formulating the President's FY 2005 Budget request for NASA, which will be released on February 2. A commission will advise on specific issues for implementation of the policy's goals within four months of its first meeting.

Today, I will walk you through the goals set forth in the policy, the major steps to implementing the new policy, the implications of this directive for NASA's programs and resources, and what the Nation's future in exploration and discovery will look like in the coming years.

Vision Goals

The fundamental goal of the new U.S. space exploration 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 the destinations for human exploration; and
- Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

Implementation

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:

SpaceShuttle—NASA will return the Space Shuttle to flight as soon as practical, according to the recommendations of the Columbia Accident Investigation Board. 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 retired when assembly of the ISS is complete, planned for the end of the decade.

International Space Station—NASA plans to complete assembly of the ISS, including those U.S. components that support U.S. space exploration goals and those planned by foreign partners, by the end of the decade. U.S. research activities aboard the ISS will be focused to support the new exploration goals, with the emphasis on understanding how the space environment affects astronaut health and capabilities and developing countermeasures.

New Space Transportation Capabilities—NASA will initiate Project Constellation to develop a new Crew Exploration Vehicle (CEV) to provide crew transport for exploration missions beyond low Earth orbit. NASA plans to develop the CEV 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.

As we begin the process of retiring the Space Shuttle from service, NASA will separate to the maximum practical extent 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. The CEV may supplement these ISS capabilities, but its design will be driven by exploration requirements.

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. Starting 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 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—NASA will enhance the ongoing search for water and evidence of life on Mars by pursuing technologies this decade for advanced science missions to Mars in the next decade. Also starting next decade, NASA will launch the first in a dedicated series of robotic missions to Mars to demonstrate capabilities that will greatly enhance robotic capabilities and enable future human exploration of Mars. NASA will conduct human expeditions to Mars and other destinations beyond Earth orbit on the basis of available resources, accumulated experience, and technology readiness.

And Destinations Beyond—Over the next two decades, NASA will conduct an increasingly capable campaign of robotic exploration across the solar system. The stunning images we have received from Mars are just the beginning. NASA will launch advanced space telescope searches for Earth-like planets and habitable environments around other stars. NASA will explore Jupiter's moons, the asteroids, and other solar system bodies to search for evidence of life, understand the history of the solar system, and search for resources.

To advise on issues for achieving these goals, the President will form a commission of private and public sector experts. Former Undersecretary of Defense and Secretary of the Air Force, Pete Aldridge, will be the Chair of the Commission. This commission will issue its report within four months of its first meeting.

NASA Program Changes

To successfully execute the exploration vision, NASA will 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.

Immediately following the President's speech, I announced the creation of the 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 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 the exploration of 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 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. 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, NASA 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. 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 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.

Budget Resources

The exploration vision for solar system exploration is affordable in both the short-term and the long-term. The President's FY 2005 Budget request for NASA, to be released on February 2nd, will be fiscally responsible and consistent with the Administration's goal of cutting the budget 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 2004 plan, an increase of around five percent per year over the next three years and approximately one percent for the following two years. Although the budget increases are modest, NASA will be able to carry out a robust exploration program. In addition to the new funding, the vision will be supported by $11 billion in reprogrammed funds over the next five years, the majority of which will come from human space flight related programs. In the next decade, retiring the Space Shuttle will free up over $4 billion per year, enabling full-scale development and operation of human missions to the Moon.

The budget strategy supporting the vision will *not* require large balloon payments by future Congresses and Administrations. Unlike prior major civil space initiatives, the approach is intentionally flexible, with investments in sustainable exploration approaches to maintain affordability.

The Nation's Future in Exploration and Discovery

As we embark on this new chapter of exploration, we are mindful of the risk attendant on that quest. And as we gather today, on this the 18th anniversary of the *Challenger* tragedy, it serves as a stark reminder of the price we pay for human exploration. It has been the case through human history. This painful reminder serves as a clarion call to redouble our efforts to undertake this new chapter in exploration in the safest manner humanly possible. As a testament to the courage of the *Challenger* crew, and their contribution to human exploration, we will designate the landing site of the *Opportunity* rover on Mars as the *Challenger* Memorial Station.

As the President stated in his. speech, we are embarking on a journey, not a race. We begin this journey 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 the 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 provided today, and I look forward to responding to your questions.

The CHAIRMAN. Well, thank you very much. It's good to have you back again, Mr. O'Keefe.

In your written testimony, you stated that NASA will be making decisions on how to best implement new programs, some of which, quote, "will not be easy," unquote. Tell us the ones that are not going to be easy.

Mr. O'KEEFE. First and foremost, the crew exploration vehicle, under Project Constellation, that we will establish—an advancement or an evolution, if you will, of the orbital space plane approach—its objectives will require the capacity to carry humans beyond low-Earth orbit. It's been awhile since we've done that properly, and the technology has changed dramatically. That's going to take an awful lot of work. And, again, the Exploration Systems Enterprise is being focused upon that very objective.

Similarly, the approach that we've talked about in the past, Project Prometheus, of developing power generation and propulsion capabilities, is not something we've done before. We have to find a breakthrough for that in order to inform these missions in a way that would be more contemporary, faster than what we typically do now. It takes 7 months to get to Mars. That's not a tolerable period of time for continuing those kinds of exploration missions.

Finally, I think the one that's going to be extremely difficult to work through, and is going to augur in favor of continuing operations of International Space Station for the foreseeable future, is to understand the human effects, human endurance challenges of long-duration spaceflight. It will be a primary vehicle and platform for the United States in order to focus on that research and scientific inquiry. Our partners will continue to look at a range of scientific endeavors, but ours will be focused primarily on that which it takes to proceed with expeditionary long-endurance spaceflight missions. Those are the ones that I believe are the near-term immediate kinds of challenges, and we'll continue along on others, as well.

The CHAIRMAN. The underlying question that all of us have is the cost estimates and the budgetary plans. When we look back at

the past cost of NASA programs, there has been one constant, and that is the costs have exceeded the initial estimates. What assurance do we have that these budgetary projections, in light of a very ambitious schedule and goals, can be met? What's different?

Mr. O'KEEFE. Sure. Well, I think you put your finger on a point that we spent a lot of time working through.

First and foremost, it is the nature of development programs that cost estimating is extremely vague. It's very difficult to do when you're developing something that's never been done before, or hasn't been tried or tested elsewhere, and, as a consequence, it means we really have to build in, a very prudent level of reserves and accommodation of what those costs will entail. And the Committee has done a very important effort, for the International Space Station. For example, really forcing the kind of fiscal discipline that's in evidence now as a cost estimate for the completion of the International Space Station that, over the course of the last 2 years, is very much a major systems integration effort that is an illustration of the kinds of things we have to do consistently in the future. We now have that experience of doing it properly. The Committee has really contributed heavily to the task of forcing that fiscal discipline, and I think we've arrived at that point.

In addition, I think the future is—if I could take issue just a bit with one element of your commentary—it is not an aggressive schedule. It is one that is very prudently laid out that intends to transition, transform, the objectives over time. And the reason it is fiscally prudent, in the judgment of the Administration—and what you'll see next week is the evidence, in detail, of it—is, again, the completion of the individual steps—return to flight, bring the shuttle back into operational service, complete the International Space Station, retire the shuttle, and then move on more aggressively, at that point, toward the continued effort of the rest of the components of the vision.

Meanwhile, there are a number of factors that are built into this, over the course of this next 5 years, which will incrementally, and step by step, move our way through that set of exploration goals the President's outlined, and establish the baseline for its pursuit.

The CHAIRMAN. Senator Nelson?

Thank you.

Senator NELSON. Thank you, Mr. Chairman.

The President made a terrific proposal that I had the privilege of being there and supporting, publicly and privately. This program is not going anywhere unless it has the full support of the White House. Why didn't the President mention it, 6 days later, in his State of the Union speech?

Mr. O'KEEFE. This program has the complete and full, 100 percent support of the President, the Vice President, the Administration, all the way through. He made an extensive speech that—again, I was just delighted you were there for, Senator—it was a very extended discussion of exactly his objectives. The Presidential directive that follows this, that's posted on everybody's website, is the most comprehensive in space policy in anyone's memory. I've only been around here a couple of years associated with this agenda, but those who have been following it longer would attest to the

fact, this is the most comprehensive space policy statement in a long, long time.

The State of the Union Address is not a tick-list of things that have been discussed previously, it is not a inventory of all other matters. And so, as a consequence, I would not have expected, given the mere 5 days before the delivery of that address, that he would have reiterated it, given the comprehensive nature of that speech.

There is not a question in my mind that the President's fully behind this, and what you'll see, on Monday, when the President's budget arrives, is a endorsement of this directive, with the resources necessary to carry it out.

Senator NELSON. I accept your answer, and I certainly hope you're right.

Tell us about—there was a lot of anticipation that there was going to be suggested 5 percent increases in the NASA budget. That was the talk for some 2 weeks prior to the President's announcement. And yet what was announced, a billion dollars over 5 years, that's $200 million a year, that's just a little over a 1 percent increase per year. How do you reconcile the two?

Mr. O'KEEFE. Again, when the budget comes out next week, what you'll see in evidence is a very clear expression of the resources necessary to carry out this statement, the Presidential directive, this strategy. And the percentage increases, year by year, are from the baseline of what the Congress enacted in Fiscal Year 2004, just a few days ago. And so what's contained in that is a specific endorsement of the specific programs necessary to carry out this directive, that—the percentages are what they are based on—once you see the detail, make a determination, as to whether you think they're adequate or not, at that time.

Senator NELSON. Well, for those of us who are going to have to carry the water for you up here, I'm certainly looking forward to seeing that.

Tell me about the hiatus. 2010, stop the shuttle, and then the new vehicle isn't ready for some number of years. As I expressed in my opening comments, isn't that a very vulnerable position for the country, to have to rely on Russian and European rockets? And isn't that a dismantling of this experienced core of NASA employees that would, of necessity, be dismantled? And isn't that bring up the fearful refrains from what we experienced 20 years ago?

Mr. O'KEEFE. Sure. Well, two points, Senator. I appreciate the point, because it is a—it's an issue of timing and sequencing that's far out in the future, but one we really need to be mindful of what its implications could be.

First and foremost, today we are engaged in spaceflight activities with our Russian partners. Right now. Over the course of this past year, we have not flown a human in space, other than on a Russian capability. The depth of this partnership, if there was any doubt about it, has been demonstrated very impressively over the course of this last year. Our Russian, European, Canadians, and Japanese partners have done a absolutely astonishing job of stepping up at exactly when we needed it most, at a time of crisis and challenge in which we could not have maintained the International Space Station or a human presence in space. And now we see the third

year of a continuous human presence, as a consequence of a collaborative partner arrangement that is working, and working very impressively.

That said, your point is well taken. I mean, the objective is to complete the International Space Station in the assembly complete configuration that the international partners will help configure and determine exactly what that will look like by the end of this decade. At the time in which the shuttle's cargo lift capacity is completed for that important mission, that's the stage in which the shuttle will retire.

Concurrently, developing the—under Project Constellation—a exploration vehicle system, the approach will be to, as soon as we can deliver that capability, to have that capable of beyond-low-Earth orbit exploration, as well as potentially that which is required for taxi between here and International Space Station well on the way. This shouldn't be a huge lift in that regard.

That said, we don't want to develop a success-oriented strategy. So there's a Catch 22 here to the extent that we end up with a capability that—what we explored and evolved under the orbital space plane approach was that a very aggressive program would yield that capability by the end of the decade. This is going to be a requirement beyond low-Earth orbit, and we want to get it right. We're going to use a page from plenty of successful acquisition experiences of a spiral development approach to launch different components in sequence as early as 2008, to begin the first of those spiral development component launches, unmanned, to test that capability to assure that we can get to a Project Constellation exploration vehicle capability. And, in doing so, that will drive the date, as opposed to any artificial date we may put on the wall.

We're trying to be as realistic as possible, to say that we're trying to drive in technology that hasn't been used for this kind of a mission, ever, to go beyond low-Earth orbit, and to not develop a success-driven strategy that is doomed to requiring a success at every spiral development phase. So, to the extent there's a gap, that will occur after the next decade, and we'll have to work out what those challenges are at that time. But it is one that we are currently managing. We'll have to work our way through whatever else may materialize, but that's not something we're anticipating, at this moment, as being a challenge in the next 7 years.

Senator NELSON. You see my concerns.

Mr. O'KEEFE. Yes, sir.

Senator NELSON. And the reprogramming concerns, as well.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Senator Brownback?

Senator BROWNBACK. Thanks, Mr. Chairman.

Administrator, I want to follow this series of questions about the retirement of the shuttle program and your relying on reprogramming of that money, much of it, to launch into the next phase, next initiative. And I think that's wise to do.

Do you have to use the shuttle to finish the International Space Station? Or could you, because there has been such a successful partnership with the Russians and the European space agencies, or—I've had a number of commercial sector people come up here,

saying, "You know, we'd like more of this action, ourselves"—could you feasibly take more missions up, with lower payload, and be able to complete the ISS in an earlier fashion, and retire shuttle sooner?

Mr. O'KEEFE. We've looked at every permutation of this, and, again, the station was designed, and the components and modules developed, in order to fit in the cargo bay. It becomes the optimum vehicle for completion of International Space Station. So this is the most efficient cost-effective way to do that.

The components and modules are stacking up at the Kennedy Space Center right now. It's quite a display. And the testing and integration work that's necessary in order to load, into cargo bay, those capabilities for the next, roughly 25 to 30 flights, will be required in order to complete station. That's been optimally configured for shuttle flights to the ISS. And any other combination would be a very inefficient, extremely difficult way to redesign that whole effort now, and would take more time. Our objective is to get to the completion of station as soon as we can, and have it fully operational for the purposes for which it was originally designed, in addition to the refocused research agenda we're now on.

So the determination is, that is the best way to conclude, and that's the direction that the President has instructed us to proceed in.

Senator BROWNBACK. I understand that, and I appreciate it. I just wonder if there is a way to do this with the partners because of the growing costs of the shuttle, the costs of running the shuttle fleet, and the projection of retiring it. I may pursue that some more with you.

On a second area——

Mr. O'KEEFE. I'd really enjoy the opportunity to do that, because the lift capacity they have is nowhere near what we can do on shuttle, but we can pursue that much further with you, yes, sir.

Senator BROWNBACK. You indicated, in your comments, that you were going to engage the commercial sector, as well, in going to the Moon. Would you elaborate a little bit more on that?

Mr. O'KEEFE. Well, it's the objective again, we haven't done this in 35 years, and a lot of technology development has occurred in that time. So one thing we're certain of is, the notion of resurrecting the way we did it 35 years ago is not an option, that's not something we're planning to do. We know how to do that, and it required brute force to leave the Earth and go that route.

So, instead, the approach will be to look at, again, a range of alternatives, some of which may be commercially driven, that, again—and I think the illumination on those options will come from the Aldridge Commission, in terms of implementation strategies and the best way they may view for us to do that, the combination of members on that Commission. To solicit the range of different commercial alternatives, as well as international partnering arrangements, a set of options on a wide range of fronts of how to implement this best is what we're looking to them to help us understand a little better.

Meanwhile, we're also going to be looking at all the commercial ideas that have been introduced and discussed, and trying to bring

those together to see how that may meet the goals and objectives we'll look into over the next few years.

Senator BROWNBACK. I certainly want to encourage that, because, to the degree that we can tap into the commercial sector, and the financing through the commercial sector, or even military issues, as well, we get into a lot bigger pots of funds to be able to do this, and other impetus to move us on forward. And it strikes me that those are out there, they're very interested, they are intrigued. They're, in some cases, pretty well financed; in other cases, could be. And I think it's going to be a key way we develop, because that's typically how we have developed. If government will open the pathway, you get Lewis & Clark out there, but not far behind are just waves of settlers coming through on their own dime to do this, and that's going to be key for us to do.

I want to say, in a final comment here, in your showing your video—I hope you show that a lot—I could feel the energy and the excitement of that, not only just what happened there, but that I'm a part of a nation that does something like this and that's willing to venture forth and to do it. And I say that selfishly, because, as a Member in this body, to encourage and to yearn people forward is an extraordinarily valuable intangible.

And I had a conversation on Sunday, with a guy I served, as a White House fellow who was a commander on a aircraft carrier, recently near Afghanistan. The reason he went to the Naval Academy was because of astronauts on the Moon. And he remembers saying, as a 12-year-old, to his dad, "I want to go—I want to be an astronaut." And his dad said, "Well, most of these guys went to the Naval Academy; that's where you have to go." And he said, "OK." He went to the Naval Academy.

Now, he hasn't gotten to the Moon, and he's not going to make it in the public sector; maybe in the private sector someday. But he's served his country as a commander of an aircraft carrier and as a dedicated American. And here was a vision sown that was harvested in a great way by this Nation.

And that's what this is. It is expensive. It does take funds from some other areas. But what value is that intangible vision by us sowing that into young kids that are 13, 14 years old, that you say, "Well, if you want to do that, you're going to have to study a lot harder." Or we sow it around the world, and how much more do we attract brainpower into the United States by sowing that into the finest minds around the world?

These are intangibles that are of extraordinary value, and I commend you for them.

Thank you.

Mr. O'KEEFE. Thank you, Senator.

The CHAIRMAN. Senator Wyden?

Senator WYDEN. Thank you, Mr. Chairman.

Mr. Administrator, for me, other than the safety issues, the single biggest issue is the question of what you can accomplish, manned versus unmanned, in terms of the agency's work. That's why I thought you all deserved a lot of credit last fall when you committed to this comprehensive cost-benefit analysis with respect to manned spaceflight.

Now we're in the situation where the President is going forward with a program that involves even more human spaceflight, and yet we don't have that cost-benefit analysis in our hand. When can we expect to get that so that we can give this project the thoughtful analysis it deserves?

Mr. O'KEEFE. Yes, sir. No, thank you. It was a very important suggestion and recommendation that you made. We have operated on that. We should have the results of that available in about 3 week's time. And so, as the budget comes out, shortly thereafter we'll see the comprehensive model of a cost-benefit analysis ready to go. It has been a real important effort, and I thank you for introducing the idea, because it really has helped contribute to shifting the way we're looking at this, in many ways.

What you'll see after next week, when you see the detail of the budget coming out, is a real—a much more balanced combination of robotic and human capabilities than I think you may be referring to here. It is intended as, part of the stepping-stone approach, the kinds of things we're doing on Mars right now, to really inform the nature of the scientific inquiry and the exploration inquiry of where we'd go, with a range of robotic missions. That's how the lunar return will be conducted; many robotic capabilities before that.

But there's a place for human requirements. One of the things that has come out, preliminarily, in this cost-benefit analysis approach is—for example, for this mission on Mars, for any one of the rovers, over the course of 90 to 120 days of scientific experimentation, a most expansive interpretation of the full volume of science we could hope to yield, short of the imagery or the actual geological content, what we're going to end up with is something equivalent to about one day's work if a human were doing it. We've got to program every single move 24 hours in advance. And as a matter of fact, we saw it illustrated on the Spirit expedition, that if you don't get it exactly right, it will do as a computer does, that all of us are familiar with that ever used a laptop, the whole thing will freeze up and shut down on you until they understand what it is you're trying to tell them.

So it takes time, and it takes a more exhaustive kind of approach to this. So if we're willing to tolerate a lot more time and a lot more money by the time you get done with it, the combination of human versus robotic capabilities turn out to be very close. But we'll show you that as part of the cost-benefit analysis. And, again, can I thank you again for prompting the inquiry which we pursued.

Senator WYDEN. Well, I appreciate your getting it to us quickly, because I can only tell you it can only build credibility——

Mr. O'KEEFE. Sure.

Senator WYDEN.—for any kind of effort to go to Mars, to have that kind of rigorous cost-benefit analysis. Because I think, otherwise, the country says, "Well, look, the Congress is just ducking the big financial questions."

Mr. O'KEEFE. Yes, sir.

Senator WYDEN. And, obviously, we don't want to have that as we try to strike the good balance between manned and unmanned in the days ahead.

Let me also ask you about this question of the agency collecting the personal data on more than ten million Northwest Airlines passengers. Apparently, this data was retained for years without the agency informing the passengers of their personal information. What can you tell us so as to ensure hundreds of thousands of constituents I have, for example, that that information wasn't shared or misused? And we've seen some e-mail to the—on this issue that would indicate that the agency's concerned that it was misused.

Mr. O'KEEFE. Yes, sir. No, I thank you for the question. And we've—since the coverage of this here in the last few days, I've really intensively looked into the detail of it.

After September 11, 2001, NASA and Northwest Airlines met to consider possible collaboration to increase aviation security. In December 2001, NASA requested this data from Northwest Airlines to analyze to see if there were trend patterns that could be devised or derived from the information. We have treated the information—it was about a three-month slice of passenger data—as very, very classified information. So, as a matter of fact, it was our biggest challenge, as I understand it, was even attempting to access the 18 disks of file, because they wrote it in a code that was not accessible to anyone at NASA. And, as a result, it is not transferrable or easily disseminated, as a result of that. It was vaulted, controlled. No one accessed it, other than the analysts.

We determined that we couldn't, after a year, download more than a day or two worth of information of any relevance and so, therefore, advised Northwest that there was little more that we could do with this, and returned all the data to them. So it was not disseminated, not released, and, to my understanding of this, was not available in—beyond the scope of what the analysts of NASA-Ames were engaged in.

Senator WYDEN. So this e-mail that we've seen—the September 23 e-mail from one of your staff, to Jay Dombrowski, that says the agency wanted to avoid creating the appearance that the agency is violating people's privacy—that simply was a concern, but you've found no evidence that the agency violated anybody's privacy or that the information was shared with anyone.

Mr. O'KEEFE. To the best of the information we have available right now, that's exactly right; there is—it was not disseminated beyond that, and everything we've heard is—and we've been able to investigate on this, would suggest that it was contained very, very carefully.

That said, Senator, this raises an important question, in the wake of September 11, so many people were looking for ways to try to protect ourselves from terrorists who would otherwise like to use commercial capabilities to kill us, and they were reaching out in lots of different directions to do that. I've been very committed to assuring that our folks understand that this really needs to, then, be mindful of the privacy rules and the Privacy Act and the implications, thereof; that we've really got to more conscious of that as we work through this.

But, in no way, shape, or form should we deter anybody in our agency from thinking proactively, aggressively, on how do we use the technologies we have to conquer this challenge against us that people would like to use? This is a delicate question, but it's one

that—I want to be sure that, in our quest to assure privacy, which we must do as a matter of law, that we also not discourage anyone from thinking actively, How do we use these technologies that—in this case, didn't work, didn't help——

Senator WYDEN. My time——

Mr. O'KEEFE.—to really go forward?

Senator WYDEN.—is up. My time is up.

I would only ask that you all try to lay out some rules——

Mr. O'Keefe: Yes, sir.

Senator WYDEN.—for using these data bases. And I appreciate your comment.

Thank you, Mr. Chairman.

Mr. O'KEEFE. Thank you, Senator.

The CHAIRMAN. I just want to add, it's great thinking, sir, but you've got to keep the privacy of the Americans foremost.

Mr. O'KEEFE. Absolutely. Absolutely. And we've done our best to preserve that.

The CHAIRMAN. Senator Hutchison?

Senator HUTCHISON. Thank you, Mr. Chairman.

I am very pleased that the President stressed that he was keeping the commitment on the International Space Station and our commitment to our international partners. And I was glad you stressed the phenomenal job our international partners have done in helping us through this crisis.

My question is, As we are looking toward the long-term future, which we all, I think, appreciate, in the short term what is the commitment to continuing the medical research, to developing and enhancing the medical research that is being done in the Space Station so that we don't, sort of, put that aside? Because when we do go back to our manned spacecraft, clearly that's going to be a major part of what we tell the American people we want to achieve for quality of life and the ability to do those experiments that cannot be done on Earth, no matter what kind of gravity you try to emulate from space.

Mr. O'KEEFE. Well, thank you, Senator. I think the short answer is, our commitment to life sciences physiological research is more focused now than ever before, as a consequence of the President's statement and his direction to us. Because the primary objective we seek to derive off the International Space Station now is a clear understanding of the challenges of long-duration spaceflight expeditionary missions, which are very much akin to the kinds of things we're doing on station right now. Mike Foale and Sasha Kaleri are aboard the station right now, as Expedition 8. They're going to be there for the better part of six and a half months. And, as a consequence, what we learn about that experience, and the life-sciences research they're engaged in, and will continue to in the years ahead, is going to be the primary focus of what we do. So the medical-derived kind of benefits that come from that for the human effects on astronauts, as well as that which can affect all of us here on Earth, as a result of what they find, is going to be a real direct benefit of it and is more intensified now. What you'll see in the budget is an enhanced position for that quality of research than ever before. We're really going to refocus everything else we're doing toward that objective.

Senator HUTCHISON. NASA has a great university consortium where you have carefully gone through the different medical schools and what their area of expertise is. I would just hope that you would start highlighting the things that are done in space. We all know the study of how human bodies react in space is important for putting people on the Moon for a longer period of time or——

Mr. O'KEEFE. Sure.

Senator HUTCHISON.—or staying in space. But the medical research that might result in a significant improvement in the treatment of osteoporosis or breast cancer, those kinds of things, I would hope you could start shipping out to the research institutions what you've gotten from space, and let's start seeing the results, because I think that will—just like these wonderful pictures will build momentum and excitement, I think that also will build momentum and excitement for the continuation of the major financial commitment we're making to space.

Mr. O'KEEFE. Senator, I couldn't agree more. On January 14, the President very specifically outlined the effects on MRIs, CAT scans, cataract detection, all these different things that have derived from this research that we've conducted for the pursuit of space exploration, and we will continue to do much more of that, and directed by him. So we clearly will enhance our efforts to move in that direction.

Thank you.

Senator HUTCHISON. Let me just ask you, in the very near interim we were going to do our next shuttle, I think you had said, in September. Now that date is a little bit off. Do you have a date that you can say would be feasible for us to do the next shuttle and also make sure, of course, that all of the safety considerations from the Accident Investigation Board are met?

Mr. O'KEEFE. No, we're still targeting that early fall, September/October timeframe. There's a window of about 30 days there, which meet the conditions that are necessary to comply fully with the Accident Investigation Board recommendations and our imposition of procedures, which is, it's got to be a daylight launch and it's got to occur in a way that we see every element and second of the flight as it proceeds during—until the main-engine cutoff. So, as a consequence, there are a number of different factors we've got to continue to monitor. And the return-to-flight task group that we've assembled of 25 experts, from management backgrounds, engineering, technical skills, et cetera, have been helping us work through each of the options to implement those set of recommendations, and there are no showstoppers we're seeing for that timeframe.

That said, I am not going to be reticent, for a second, to delay that if there's anything that gets in the way of doing this in a way that assures that we're fit to fly. I'm not going to be driven by a calendar or a date. And that's the general frame that we're looking at. But I think it's critically important that we be looking at a milestone, not a calendar, to drive that set of objectives.

Senator HUTCHISON. Thank you, Mr. Chairman.

I just hope so much that we can start seeing the new medical research results. We all know the old results, and they've been fabulous.

Mr. O'KEEFE. Sure.

Senator HUTCHISON. And I just think it would build excitement if we can bring out more of the new results to show why we are continuing, to the American people.

Mr. O'KEEFE. Stand by. I think with the President's direction on this focus on life sciences in the future, it's impossible to predict what's going to happen, but I think we're going to see some really profound changes on that front, as a consequence of really concentrating on human effects, long-duration spaceflight, physiological consequence, that will have derived advantages for the medical community, to be sure.

Senator HUTCHISON. It'll be very exciting.

Thank you, Mr. Chairman.

Senator STEVENS. Mr. Chairman——

Mr. O'KEEFE. Thank you, Senator.

Senator STEVENS.—if I could just ask just one question——

The CHAIRMAN. Senator?

Senator STEVENS.—to highlight Senator Brownback's statement. How many hits did you have on your websites after those landings on Mars?

Mr. O'KEEFE. Thank you, Senator. In the last 27 days, we've had four billion hits—billion hits—to the NASA Website. All of last year was 2.8 billion. That was four times the amount of any other year. So in a span of 27 days, we've already exceeded the annual highest level we'd ever had, and last year was a pretty active year. It was amazing. The overwhelming interest is just phenomenal.

Thank you, Senator.

The CHAIRMAN. Senator Breaux?

Senator BREAUX. No wonder the computers on Mars crashed.

[Laughter.]

Senator BREAUX. Got an overload problem.

Administrator O'Keefe: It's true.

Senator BREAUX. Two points, the first one being, on the vehicle that we're talking about being the next-generation vehicle, we went through this process, probably before your time, with the X–33, the Venture Star plane that was out on the table, withdrawn, dropped. And then we had the orbital space plane, OSP, that was out there; companies started looking at it, got excited, you know, got geared up, and that's gone. And now we have the CEV, which is the crew exploration vehicle.

I would hope that we decide on what we want to do. I mean, the direction, again, is what I'm concerned about. We start, we stop, we change, and that's got to be very difficult for the private sector to become involved into the plan and put together consortiums to make these things work.

So can you tell us, if you know, Mr. O'Keefe, where are we on this third plane that I'm hearing about? I mean, do we have a concept? Do we have more than a concept? Do we have enough to say to companies, "Go out there and start looking at how to design, test, and build this vehicle?" Where are we on that?

Mr. O'KEEFE. Yes, sir. No, there is a little bit of a difference in the example you just used that I'd like to point out, just for a second.

The X–33, as I understand it, back in the mid to late 1990s, was a first attempt, or maybe a second or third attempt, at trying to achieve a horizontal launch, a capacity to fly off a runway and achieve low-Earth—beyond-low-Earth orbit or in-low-Earth orbit from that kind of stationary position. It required, in the words of several industry folks that I've talked to, at least two inventions and at least one suspension of the law of physics in order to do this. And, as a consequence, we don't know how to do that yet.

This is not dependent upon that. Matter of fact, if anything, the whole approach the President's program is dependent on that has been really a—it was a dogged issue that we worked through all the way through the six-month interagency process—was that there be nothing here based on the use of an element called "unobtainium" or anything else. This is something we've got to have the capacity to do, and it's a stretch; it's an aggressive application of today's technology, but not something that requires a miracle for an invention.

So what you see in the Project Constellation exploration vehicle is a logical extension of the work we did on orbital space plane. In so many ways, there's an awful lot common between the two. The difference is that its objective, its goal, is to go beyond low-Earth orbit; whereas, the orbital space plane would have permitted a lot of different designs in order to simply achieve low-Earth orbit to and from International Space Station——

Senator BREAUX. How would——

Mr. O'KEEFE.—250, 300 miles up.

Senator BREAUX. Excuse me for interrupting, but how would the CEV be launched?

Mr. O'KEEFE. The same way that the orbital space plane, off of an expendable rocket. That's the intent.

Senator BREAUX. Do we have that rocket capacity now?

Mr. O'KEEFE. That's the issue we're going to need to continue to work, and it was the same one we were working on OSP. And I think it really is going to depend on what combination of capabilities do you put on a Project Constellation exploration vehicle, in terms of longer-duration spaceflight that may require more lift? And that's something we're going to need to look at.

Senator BREAUX. When will NASA be ready to say to industry who will be involved in developing and building this ship, "Here's what we want you to do"?

Mr. O'KEEFE. Pretty quick. I think the objective was—on OSP—was to look at them responding to a proposal here, during the course of this calendar year, and aggressively, if we could have awarded something by August. We're going to need to spend the next 6 months with them and everybody else—commercial ideas, the whole bit—trying to put together a set of baseline requirements, which, again, are derivatives from the OSP. We're not starting with a clean sheet of paper; this is a direct extension of what's involved there. And I suspect that many of the same designs that the industry was looking at will have great applications here, as well.

And so, as a consequence, we're going to do this collaboratively with them in order to find what are the best approaches to this, and solicit other commercial ideas that may exist out there.

Senator BREAUX. OK.

The second point I would ask about is the concern about the start-stop-stop-start, and the continuity of the work force. I mean, we, down, as you know quite well, in Michoud, in New Orleans, have this huge facility with thousands of employees, and my real concern, as I look at the President's plan, that we'll probably have as much as a five-year gap after the shuttle is completed its work and the time when we start with this new CEV vehicle that is now only in the very minute planning stages. What do we do to keep the continuity of the work force? I'm really concerned. These folks have—if they lose the work, they're gone. You have to restart, restop. I mean, how do we address that continuity of service that we—is so necessary to get what you need to accomplish?

Mr. O'KEEFE. Yes, sir. No, it is a critical factor that we really need to work the details of, that have got a few years out. That's not to say we're not going to start right now trying to sort through what those consequences are.

At least for the next 4 years, you're looking at production of the external tank, et cetera, that are necessary to fly a shuttle. There are a number of different options that we'll look at, shuttle-derived approaches, for lift capability for the Project Constellation exploration vehicle. That's not yet determined, and we're looking for creative ideas from the industry to do that.

I'm not convinced there's going to be a gap or a hiatus there. Because, again, part of what is—in the dialogue with Senator Nelson a little bit earlier—what we're pursuing is an acquisition strategy of a spiral development, of which the first spiral of the Project Constellation exploration vehicle, unmanned, will be launched as early as 2008 and a little bit later this decade. Potentially, we could see a lot of aggressive, heel-toe kind of transition occurring, depending on how we do this, and we're going to have to factor that in when we make determinations of the right way to do this.

So, a lot is not yet determined, in terms of what the transition looks like five and 6 years down the road. We're really concentrating on this coming year in order to position ourselves to make sure that the answers for that transition, 5 and 6 years down the road, are sound.

Senator BREAUX. OK. Well, I'm glad you're looking at it, because it's obviously very, very crucial to keep that supply of the workforce there——

Mr. O'KEEFE. Yes, sir.

Senator BREAUX.—doing something. They're not just going to be able to sit for a gap of several years.

Thank you very much.

Mr. O'KEEFE. No, thank you, Senator. Again, I think to look at the Project Constellation vehicle as a natural extension, not a new things, from what OSP work did. That was a lot of valuable time spent to do that. It worked out exceptionally well. We learned a lot from that experience, and we're just naturally evolving it to a more expansive effort that has a mission objective beyond low-Earth orbit. It draws on the very same kind of capabilities, no doubt about it.

Senator BROWNBACK [presiding]. Thanks.

Senator Allen's next.

Senator ALLEN. Thank you, Mr. Chairman.

Administrator O'Keefe, it is always a pleasure to listen to you, and I think your leadership, enthusiasm, and adherence to sound fiscal policies gives us some confidence—gives me a great deal of confidence in your ability——

Mr. O'KEEFE. Thank you, sir.

Senator ALLEN.—as you go through these—you formulate the strategic plan—but then also as you answer very probative and logical questions from my colleagues—how you will adapt as you learn more, the steps in the strategic plan are sequential, you meet each goal and, from there, take on the next step of that long-range goal. And it is important to have a mission and a goal, as opposed to just floating around like loose seaweed in the tide. You actually have certain missions, and I think that is important. You know, you're going downfield. That's important.

The workforce issues that Senator Breaux brought up generally with NASA are very important. I've been one that's—I mean, I am going to ask you questions on aeronautics, but you also look at the fewer and fewer engineers with aeronautical engineering degrees, and we see that in a lot of areas in our country. That can be made up, from time to time, by bringing in people from other countries, which is great, and you all have done it, and that's to be commended. However, just like Senator Breaux said, though, is, if you curtail any of these areas, it's not as if you just snap your fingers and all of a sudden there are aeronautical engineers or those who have the capabilities, and it also slows down your implementation as you're trying to get those folks up to speed working as a productive team.

And, clearly, as you saw the celebrations there, you didn't know what each was doing, but there were certain teams that had certain aspects or components of those landings that, "All right, great, the balloons or the air bags have deployed. That's what we were supposed to get done. Now that it's landed, great, that's wonderful. Let's see if it opens." Each one has a certain responsibility, and you do work as a team.

Now, insofar as your aerospace technology enterprise, aeronautics enterprise, and so forth, Lee Forsgren forwarded me and other Members of the Committee, your January 15 letter to Senator McCain. And in reading through it—and I'm going to ask you to put some more meat on the bones, if you could—theoretically, it all sounds very, very good. I like that the aeronautics enterprise is going to emphasize the importance of aeronautics research and related technologies for our country's civil and defense interests; they'll perform research, develop and validate innovative high-payoff aeronautics and related technologies that'll enhance our security, through partnerships, obviously, with the Department of Defense, the FAA; and work in partnership with industry and also academia to get this transfer, the same sort of things that Senator Hutchison was talking about—more in the space exploration, but having the applicability to real-life, real present concerns we have, whether it's in medical sciences or other.

Now, my concern with this is, will this reorganization of the aerospace technology enterprise—what will be the impact of that on the aeronautics budget? And do you see the new aeronautics en-

terprise participating in this new vision? There is some carryover from aeronautics, obviously, into space exploration, as well.

So those are two questions. First, what will this initiative have as an impact on the aeronautics budget? And how will they be involved in the overall new vision?

Mr. O'KEEFE. Yes, sir. First and foremost, I want to thank you for raising the workforce challenges that we're facing, and to thank the Senate for enacting and passing on S. 610, Senator Voinovich's bill that—right before everybody went out of session in December; it's in the House now; they're due to call it up pretty quickly—I'm advised here, this week—that gives us the kinds of tools necessary to recruit/retain the kinds of skill mixes you're talking about. We've got a professional opportunity here. Matter of fact, I'm just told now that S. 610 is on the House floor right now. So, you know, this is a year and a half in the making. Thank you very much for passing it. It was a critical piece of legislation that we've really been wrestling with in order to get the kind of tools necessary to recruit and retain the workforce capabilities that are there. So it is a major achievement; and if we get it enacted, the President will sign it rapidly. I can see that coming right away.

In terms of the aerospace and aeronautics enterprise approach, it is no accident that the day after the President's vision announcement, we specifically looked at establishing an aeronautics enterprise to make sure that concentration and focus dominantly resides within what we do in the agency. Because so much of what we're engaged in, as you very accurately stated, is applied to a range of different capabilities in the space exploration activity, as well as the civil aeronautics kind of applications we're engaged in.

Airspace management, continued efforts. Matter of fact, in another 3 weeks we've got a demonstration of the hypersonic X–43 that will be followed through, in terms of what our aeronautics efforts are producing now. And the objective will be to, again, use the materials research, the aeronautic engineering capabilities there—at Langley, at Ames, at the Glenn Research Center, the very prominent aeronautics centers that we have within that community—to continue to contribute, not only to this set of vision objectives for U.S. space exploration the President's enunciated, but also to our fundamental requirements for aeronautics, which is part of our name.

Finally, putting the NASA Engineering and Safety Center at Langley is not there by accident. That's the center that really has the highest concentration of aerospace engineering expertise, from materials research and a range of different capabilities that is necessary to examine trends, patterns, et cetera, on a wide range of aeronautic, as well as spaceflight, capabilities, that every center, every program has the opportunity now to draw from that expertise that's resident right there. It is very consciously established at that location, and very specifically there for the purpose of, not only retaining those capabilities, but using them to solve, not only aeronautics challenges, but the range of space exploration issues that we're looking at across the board. It's going to have a very cohesive role, I think, in the larger NASA program objectives that we've articulated.

Senator ALLEN. Well, Mr. Chairman, I'll be looking forward to working with you—I know the budget will be coming out—and seeing how it works.

Mr. O'KEEFE. Yes, sir.

Senator ALLEN. You also should be looking for a letter from Senator Dodd and myself, not just to you, but to everyone from Defense to FAA, TSA, NOAA, and others, insofar as aeronautics. Because I think the vast—I know the acting chairman, Senator Brownback, and others really recognize the importance of our preeminence in aeronautics, and we cannot lose that preeminence, for our security as well as for jobs here in this country.

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

Senator ALLEN. And I look forward to continue to work with you, Mr. Administrator.

Mr. O'KEEFE. Thank you, Senator.

Senator BROWNBACK. Senator Dorgan?

STATEMENT OF HON. BYRON L. DORGAN, U.S. SENATOR FROM NORTH DAKOTA

Senator DORGAN. Mr. O'Keefe——

Mr. O'KEEFE. How are you, sir?

Senator DORGAN.—first of all, let me congratulate NASA on the recent successes. I think it's breathtaking to watch what is happening with the landings on Mars.

Second, let me say that when you were nominated by the President, I didn't have the foggiest idea whether you would do well or do poorly, but I must tell you that I'm very pleased that I supported your nomination. I think you, personally, have done an excellent job under some very difficult circumstances.

Mr. O'KEEFE. Thank you, sir.

Senator DORGAN. I'm sure you could probably point out where you might have done better, but, at least as an observer, I think you've provided strong leadership at a time when it's needed, and I wanted to say that to you, because I did support your nomination and am pleased I did so.

Mr. O'KEEFE. Thank you, Senator.

Senator DORGAN. I also believe that when a nation stops exploring, it stops progressing. So I believe that exploration, and I believe the mission of NASA, is important.

But I do want to ask about the President's proposals. You indicated that they were developed through interagency task forces and so on. Was there any other outreach, any other inquiry by NASA with experts around the country about what do they think we should be looking at 10, 20, and 40 years from now?

Mr. O'KEEFE. Yes, sir. The interagency process we conducted internally also drew on the opportunity to meet with various Members of Congress, who had very specific goals and objectives they thought should be enunciated, as well as the very helpful hearings that this Committee and your counterpart Committee in the House conducted to really examine what are the alternative views of what the vision and strategy objectives should be. We heard it, we listened, understood that, and also went out and solicited other views, as well.

But not to leave it at that, one of the things that the President was particularly focused to assure that some of the helpful suggestions that Members offered and that a commission be set up for the purpose of assuring that we solicit more broadly what those implementation strategies are. And Senator Brownback and others were very instrumental in advancing that particular objective. We heard that. The President was struck by that notion of saying, "Let's assemble a commission." Pete Aldridge and the Commission that will be charged here in the very short number of days ahead to begin looking at implementation strategies—how do we look at commercial, international participation, a range of other factors, workforce issues that Senator Allen raised, others that need to be factored in as we move forward to accomplish this objective—that's what this Commission will be doing—we'll be supporting it, participating in it—that is due to provide its findings here by this summer.

So we're working this real-time, and moving ahead with the strategy and the program the President will unveil on Monday as part of the President's budget program, and be informed by the views that come externally, as well, from the Aldridge Commission.

Senator DORGAN. And while I said I support space exploration and believe it's important—I believe a country needs to continue exploring—it is expensive, costly. And I don't want to be a wise guy, but I must say, we've been promised the moon before, particularly in fiscal policy. We, as you know from the announcement this week, have a $477 billion deficit this year, but it's really $630 billion, because the 477 counts the Social Security Trust Fund. So we have the largest deficit in human history. It's a very significant problem.

And so the question, I think, for all of us is not just the goal, but how do we pay for this? How much is it going to cost? And I've observed that, at least in the initial portion, you're talking about reprogramming $11 billion, I believe, in the 5 years, from the current NASA budget, or current NASA expected appropriations.

Can you tell me—my expectation was, from previous testimony, that we were pretty tight. I mean, we've seen budget cuts in NASA. And so how do we reprogram $11 billion without substantially affecting many other critical things that NASA said it needs to do? Can you talk us through that fiscal policy or the——

Mr. O'KEEFE. Yes, sir.

Senator DORGAN.—I guess, the financing issue?

Mr. O'KEEFE. Well, thank you, Senator, for a very important question.

As a general budget strategy, let me assure you that the President's budget, when it arrives here next week, will follow through on the commitment he made, and has articulated as a discretionary spending increase of less than 4 percent, with the objective, as well, over the next 5 years, of driving down the deficit projection to half of what it is today. So that's the overarching economic policy. And the program that we are engaged in, and that he has directed us to follow through, is part of that plan. We are a component of it.

The specific aspect that's in your packet, I believe—just to turn it into a eye chart for you—is, in this specific five-year plan, the numbers that will be supported in the President's budget that we'll see in great detail next week supports a transition or a trans-

formation, if you will, more toward the exploration missions that he's directed; and then, in the out years, assumes not more than the rate of inflation for an increase beyond that.

So we've really put this through the sanity check to assure that we're not passing a balloon note off into the next decade, and, instead, looking at what it will require in that transition. So all the elements of the plan were developed very specifically to conduct the transition and an ultimate transformation of capabilities to move more in the direction of the exploration missions he's directed. And it fits within the parameters of the overall economic strategy I talked about at the very beginning.

Senator DORGAN. Yes. I want to talk with you more about that at some other time.

But I might say that the two landings on Mars demonstrate the incredible value of unmanned space exploration, as well.

Mr. O'KEEFE. Yes, sir.

Senator DORGAN. I mean, there's much to be gleaned from that.

And I would also just, finally, like to say this. I hope, while I complimented you, and my colleagues, I'm sure, have the same feelings about your stewardship, I hope you will pass our compliments along to the men and women of NASA. When I saw that film—I mean, I wasn't in the room, and you were, when they discovered that they had landed Spirit successfully on the surface of Mars—it is an extraordinary technical achievement. I mean, almost one that's hard for us to fathom because we're not scientists. But I hope you will relay our congratulations to the men and women who work for NASA, as well.

Mr. O'KEEFE. Oh, thank you, sir. It was a heart-stopping experiencing on both occasions, particularly when you see the animation of that thing bouncing. I mean, that was enough to stop you cold all the way through this. It's an amazing feat, and one that is just staggering to grip the fact that this is a hundred million miles away, and we're communicating with these two capabilities that are just absolutely extraordinary, and we dared not dream it would have been this successful.

Senator DORGAN. And especially following such a devastating tragedy that I'm sure affected, personally, everyone who works for NASA. To have this success was really critically important. But it describes, again, how unmanned space exploration can be very helpful to us, and it describes the technical capability and the spirit of the folks that work for NASA.

Mr. O'KEEFE. Thank you, Senator. Appreciate it very much. I'll pass that along.

Senator BROWNBACK. I want to add my support to those comments, too. Gave me a lot more feeling of security in the air bags in my car——

[Laughter.]

Senator BROWNBACK.—when I saw that taking place.

Senator Ensign?

Mr. O'KEEFE. It's the same technology. That's the thing. It's the very same idea.

STATEMENT OF HON. JOHN ENSIGN, U.S. SENATOR FROM NEVADA

Senator ENSIGN. Thank you, Mr. Chairman.

Just as a little background, so you know where I come from, personally, when I was in high school, I was one of those kids who wanted to be an astronaut and wanted to go to the Air Force Academy; and ended up being an alternate to the Air Force Academy, so didn't pursue that. But always been fascinated with space, loved the work the Hubble Space Telescope has done, followed NASA's accomplishments. I can't tell you how many of the launches of the space shuttle that I watched. I remember, as a kid, watching all of the Apollo. So it's been a real fascination for me, personally, over the years.

Now, having said that, in the last several years—and I think that the Space Station has been a big part of this—I've become more concerned about what NASA is doing. The Space Station, you know, original budget was projected to be somewhere around $8 billion. My numbers are correct, somewhere in there?

Mr. O'KEEFE. Yes, OK, the history of this is tough to trace.

Senator ENSIGN. Yes.

Mr. O'KEEFE. In the course of the last couple of years I've been there, it is a firm number, and we know where it's going; but what it originally started at, it's been devolved several times and redesigned, and I can hardly even figure out what the original idea was anymore.

Senator ENSIGN. I understand some of the politics in working with some of the other countries, and dumbing down some of our science and various things that we've had to do, and budgetary things. And the problems that happened with the Space Station, illustrate, not necessarily that it was the scientists' fault, or, part of it Congress' fault, performing budget cuts, I've—actually have one of the Nevadans that works on this—I used to ride on the airplane with him, talking about it all the time. We used to come back here, and he was hired to evaluate the problems with it.

The bottom line is that the projections are usually here, on big government programs. And certainly this is one of those. The reality is the numbers are usually, to use a scientific term, a quantum amount above whatever the initial projections are. And especially when you're talking about vision things, because you have no idea what the costs are going to be, and we have no idea what other kinds of outside influences that Congress may go through at the time to affect that, and that's what happened with the Space Station over the years.

When you introduce humans into spaceflight, we know that the cost dramatically goes up. There was a comment about, if people were on Mars today, the benefits that we would have—well, they wouldn't be able to smell it, they wouldn't be able to touch it, they wouldn't be able to feel it, and their eyes aren't as good as what the robot's eyes are. And I guess the point that I'm making is that, you know, as a country, I think that we do have to reevaluate the idea of putting people in these projects, because of the enormous cost. I believe in continuing space exploration, but I think we have to take a very hard look at the cost benefit of having people in space. Does it really benefit us as a species—even our curiosity,

does it really benefit us that much, going forward, compared to the huge, huge difference in cost that it's going to take to get people there, along with the risks?

And speaking of the risks, people will die in space exploration; there's no way to stop it, there are risks involved; we saw that last year—well, when that happens, then we reevaluate budgets, we put things on hold, we stop. If one of those rovers went up there and it crashed, well, it would be a scientific setback, but it wouldn't be a tragedy where the whole country would be saying, "Put an end to the space program." And I just want to put that out as a cautionary look, as you are going forward.

I appreciate the President's vision for this, but, you know, not to be a naysayer, but I think that some people have to raise the voices and ask the tough questions. What is the benefit of putting man as part of this? So I guess that that would be my question for you, Are you all weighing that huge cost that it's going to take to put men in, versus the benefit?

Mr. O'KEEFE. Absolutely. No, thank you, Senator. It's a very important question, and one that I think really has to be wrestled with, not just once or trying to be definitive in one circumstance, but every single day we've got to put it through the sanity check that we are designing missions and approaches that can only be accomplished by human involvement. And if we can't, then we really ought to be doing it more robotically. And I think that's the approach, the balance you'll see in the President's program here.

Let me just give you a couple of data points, though, of what's involved. We've talked a little bit—with Senator Wyden a little bit earlier—of a cost-benefit analysis approach——

Senator ENSIGN. Can I interrupt you, just real quick?

Mr. O'KEEFE. Yes, sir.

Senator ENSIGN. You said that "only" could be accomplished best by robots, it's only what could be accomplished with humans that you would have humans involved with.

Mr. O'KEEFE. Indeed, because there's a cognitive capacity that we can't build into a robot, hard as we might try. It's also some efficiencies that go with this. The cost-benefit analysis that, again, Senator Wyden prompted us to think about and that we'll have available here in a few weeks, really goes through, which is—again, if you look at this Mars mission, on just one of them, rover—Spirit or Opportunity, either one—the overall scientific package over the 90 to 120 days it's going to be really engaged in the scientific pursuit—geological robotic capabilities, and so forth—could be accomplished by a human being in 1 day. OK? It's just—there's mobility, capacity to move around, do things, make judgments at the time.

We get 2 week's worth of time, probably, on Spirit that we're going to spend working out the mechanical challenges of a computer glitch, to be just real blunt about it, that occurred on Spirit last week. That's the kind of thing that could, I don't know, arguably be settled very rapidly with someone there looking at it. It really takes a different condition.

That said, we can't put anybody there. We don't have the capacity to put someone on that planet right now. They couldn't stand the physiological consequence of taking the trip, much less being there. We don't know how to do that yet.

But there are a whole range of things that we could accomplish differently, and could do it more efficiently, and could only accomplish with human beings if that were the case.

Hubble is the perfect example of this. John Grunsfeld, sitting right here, is the chief scientist of NASA. He's been to Hubble twice. And the only reason why that capability continues to operate today is the servicing missions that were conducted by human beings. And, indeed, as good an astronomer as he is, as good a scientist as he is, as good an astronaut as he is, his primary qualification for the task, given the fact that all the controls on the Hubble are on the left side, is, he's a southpaw. His capacity to be able to use a catcher's mitt to make adjustments on this turned out to be one of the greatest attributes going. We don't have an autonomous robotic capacity to do that.

And, as a consequence—looking at the risk that we took for him and his colleagues to go there in the past, are now determined to be higher than we should have ever accepted, given what we know from the Columbia Accident Investigation Board report and all the recommendations it levied for us to fly safely in the future. And, as a consequence, those kinds of missions, even though they can only be done by a human to do this properly, are the kinds of things we've got to dispense with and we're making the choice about because of the risk involved. Those are the kind of gut checks we have to make, but also compare it to the cases where, when we have the capacity, discern very carefully when you can only bring human capacity to bear to get the outcome you're looking for.

Thank you——

Senator BROWNBACK. Senator Smith?

Mr. O'KEEFE.—Senator. It's a very important set of questions, and one we take very seriously, and I appreciate your inquiry to it.

STATEMENT OF HON. GORDON H. SMITH, U.S. SENATOR FROM OREGON

Senator SMITH. Thank you, Mr. Chairman.

Mr. O'Keefe, I believe my colleague from Oregon, Senator Wyden, may have already touched upon this issue. You should know, both of us have been inundated by concerned Oregonians, who have wondered if their privacy has been violated, and it has to do with the data-mining project that NASA undertook after 9/11. I think it's understandable to Americans that all government agencies are trying to figure out, "How can we help?" And yet many are wondering if the airlines they rode on—Northwest in particular, JetBlue another—cooperated in a way that compromised privacy of individuals. In fact, I understand that JetBlue is subject to some class-action lawsuit. And I wonder if you have some thoughts about that.

But I wonder what steps, having undertaken this, NASA can give, in terms of assurance that it took steps to protect privacy, and I'm wondering what you learned—having protected privacy, what then did you learn about protecting national security in airline travel? Frankly, I had never realized you were in airline travel security, but—this was all new to my constituents, but it hit the press and created a firestorm.

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

This was an incident that, again, we are very conscious of, the Privacy Act and its implications. And once the data was released to NASA by Northwest Airlines, I'm advised that there are two things that really mitigated against any real proliferation of the information.

The first one was the security procedures we used. They were 18 disks that contained the information over a three-month span, and it was vaulted, as in put in a deep, dark safe, when it was used. There were a very specific number of folks who were working on it—very small number—who were working on the analysis. And it leads to the second issue, that—basically conquered the reason why we couldn't really contribute much is that the data compression that Northwest Airline uses for its information—we could only extract, from that 3 months of data, 2 days worth after a year worth of trying to redesign the information just to download it. And it yielded nothing.

So, as a consequence, just the technique they were using at Northwest—and other airlines, I suspect—for how they used the information is not easily transferrable to anybody, and it sure wasn't to NASA.

We were asked to get into this because we are engaged in a number of airspace management approaches, various, again, high-computation kind of analysis efforts that have gone on, and there were those who thought there may be some way that we could help in this case. Turned out we couldn't. We turned over all the data back to Northwest Airlines. It was not distributed beyond the very limited number of analysts who were engaged in it, and it proved to be something that was way too hard a climb because of the nature of the data that was compressed in the first place.

The privacy issues are terribly important, and it's ones that we want to remind our folks of constantly. That said, I want to be able to assure and encourage our people to think about how we apply our technology toward the kind of activities that would thwart anybody from wanting to use a commercial airline against any of us in the future.

Senator SMITH. Well, I appreciate you speaking of it. I know that my constituents are supporters of NASA. So am I. But we're concerned about this. And what I take from your answer and also from your office's response to my letter——

Mr. O'KEEFE. Yes, sir.

Senator SMITH.—to you about this. I appreciate the response that no privacy was violated in a way that resulted in damages to citizens. Obviously, that awaits a jury to say whether any airline is liable, but, at least from your perspective, no damages were inflicted upon individuals by the loss of their privacy.

Mr. O'KEEFE. Yes, sir. That's the information I have, and it's—that's based on the investigation we conducted to see how far this went. That's the findings that our folks have come back with, in terms of what the containment of the information was in the first place. We're very mindful of that.

In this post-9/11 world, we're all learning different ways that we've got to protect information like this.

Senator SMITH. Well, I appreciate that very much.

And I also want to second the comments of many of my colleagues, who are curious about this, the manned projects to the Moon again, and to Mars, wanting to be supportive, also needing to balance budgets on Earth, and wanting to know what is the value that we can glean from actually undertaking the risk and the cost of putting human beings up there. Is there a cost-benefit relationship that we can defend to our people? And if there is, I think America is an exploring nation and wants to know more of what's out there. But those are the questions we need to have asked. And I think you're telling us today, you're prepared to answer them in the near future.

Mr. O'KEEFE. Yes, sir. Thank you very much, Senator. That's exactly it. And the President's budget, I think, will address many of those issues, and in the context of his overall economic policy, which is well within the context of this.

Senator BROWNBACK. Thank you.

And thank you, Administrator. You've been very candid and thoughtful with your comments. It's been a delightful hearing, you can get a real sense of feel of the people up here.

I would add, I'm delighted to see the President shooting to cut the budget deficit in half in 5 years, and reprioritize, because to me that's compassionate conservative ideology. There's enough money in the budget; it's just not programmed in the right places.

I think we ought to shoot to balance the budget in seven, which is a target we've moved toward in the past, and something I think that we ought to engage again, and yet still do things like what you're directing to do, and show the people that when you get nearly a $2 trillion budget, there are enough funds there to do things, it just frequently is not in the right places where you want it, and priorities change, and you need to shift money around. And that's the tough work of governing, that we're going to need to show that we actually can and will do things like that, and you don't need to raise taxes, and you need to keep the economy robust by keeping taxes low to get these things done.

So we've got our job cut out for us, as well. You've laid out a great vision for us, and you've been very candid in your thoughts. I do encourage you to meet with Members privately, as I know you do, because a lot of people continue to have other thoughts and comments.

Thank you for your presentation today.

Mr. O'KEEFE. Thank you, Senator.

Thank you very much. And your summary comment, I want to associate myself with exactly. That's precisely where the President's going, and that's precisely what this program incorporates, and it does show those tradeoffs, and stays within the fiscal discipline that he's imposed on all of us. And so I'm extremely heartened by this direction, and I appreciate the reception of the Committee, as well, to hear it out.

Thank you, sir.

Senator BROWNBACK. Thank you.

We'll now have a second panel—Dr. Louis Friedman, Executive Director of The Planetary Society; the Honorable Neal Lane, University Professor, Senior Fellow of the Baker Institute at Rice University; Dr. Howard McCurdy—he's Professor, Department of Pub-

lic Administration, American University; and Mr. Richard Tumlinson, Founder of Space Frontier Foundation.

If we could have, gentlemen, all of you at the table, we'll get going as quickly as you're there.

Gentlemen, I'm sorry we dragged on a bit, but, as you can tell, there's a lot of interest, we had a lot of Member participation. And it's a good-news story, instead of the bad-news story we've generally had.

Dr. Friedman, let's start with your testimony.

We will include each of your full written statements into the record as if presented. I would encourage you to summarize, as best as possible, on the key points, to make sure that we get really what is the heart thrust of what you're after.

Dr. Friedman?

STATEMENT OF LOUIS D, FRIEDMAN, EXECUTIVE DIRECTOR, THE PLANETARY SOCIETY

Dr. FRIEDMAN. Thank you, Mr. Chairman and other Members of the Committee. It's a pleasure to be back here. I used to work on the staff of this Committee, and it's always a pleasure to come back.

Senator BROWNBACK. Welcome.

Dr. FRIEDMAN. Thank you for the opportunity to comment on the national space policy directive issued 2 weeks ago by President Bush. Both its title, "Renewed Spirit of Discovery," and its stated goal to extend human presence across the solar system, capture a spirit that we, at The Planetary Society, have long advocated. The new policy directive states clearly that the human space program will no longer flounder without a compelling goal, and will finally set its sights on other worlds. Understanding and extending life beyond Earth is the only purpose that justifies the cost and risk of human spaceflight. Restoring exploration as the raison d'etre of the space program is a welcome development to those of us motivated by science and exploration.

The goal and vision are terrific. Setting goals, providing a broad vision is the President's job and that of you and your colleagues. The challenge in question now is implementation. Other space visions have turned out to be counterproductive in advancing space exploration, even those with noble aims—the shuttle, the Space Station, and the 1989 Moon-Mars initiative, for example. A great deal of public, political, and international constituency building will be required.

The welcome first steps in this new policy include retiring the shuttle quickly after completing assembly of the International Space Station; separating crew and cargo, not just in launch vehicles, but for transportation to the International Space Station and for launching exploration missions beyond low-Earth orbit; building a new crew vehicle that would provide crew transportation for missions beyond low-Earth orbit; and conducting robotic exploration across the solar system for scientific purposes and to support human exploration. This is particularly welcome, for the policy is not limited to the Moon and Mars; it supports science even to understand the history of the solar system. We have previously advocated all of these steps.

Funds for vehicles and human missions beyond Earth orbit are not yet allocated. The projected NASA budget may be inadequate for dealing with all the technical challenges for conducting human missions on the Moon and sending them on to Mars. But ways to lessen the cost of human exploration of Mars, including from international partnerships, should be learnt during this period.

The Planetary Society urges that a robotic Mars outpost be set up for—at a potential human landing site for placing robotic infrastructure that can increase reliability and safety, and lower costs for human missions. A Mars outpost is an appropriate goal for the international robotics Mars programs in the next decade.

Cost is determined by requirements. The technical steps cited above, the Mars outpost, they can reduce the costs of sending humans to Mars. Conversely, Martian exploration will be more expensive if it includes extensive lunar objectives, prohibitively so if they include developing permanent lunar bases or open-ended exploration for speculative lunar resources.

Much rhetoric, and even some of the official statements accompanying the directive, have been confused or misleading on this subject. One even called for launching spacecraft from the Moon into the Solar System. There's probably no more expensive way that could be devised to reach Mars.

Fortunately, the President's policy itself does not call for these things. It says only that we should use lunar exploration activities to further science, develop and test new approaches, technologies, and systems, and including the use of lunar and other space resources—an emphasis—to support sustained human exploration to Mars and other destinations.

The costs for any proposed use of lunar resources should be estimated and compared with alternatives. The topic must be subject to economic analysis before any commitment to such a program is made.

While the United States and Russia have been to the Moon many times, it is a target of international interest. Europe has a mission to the Moon right now. Japan, India, and China all have missions in development underway. International cooperation is supported in the policy directive, and we urge that the United States, with other space-faring nations, cooperate and coordinate their robotic lunar missions. This could pave the way for international human crews and missions to the Moon and to Mars that would lower the cost in the long run.

The Planetary Society co-founder, Carl Sagan, wrote, "There's plenty of housework to be done here on Earth, and our commitment to it must be steadfast, but we are the kind of species that requires a frontier for fundamental biological reasons. Every time humanity stretches itself and turns a new corner, it receives a jolt of productive vitality that can carry it for centuries. There is a new world next door, and we know how to get there."

Only at Mars will we begin to learn whether humankind is limited to a single planet. Only at Mars will humans be able to investigate the key questions about life. These are the great human purposes for which we send humans to space.

The lure of Mars was dramatically revealed by the enormous public interest and excitement that attended the landings of the

Mars rovers this past month, and which we saw graphic evidence of this morning, the presence of five robot emissaries from Planet Earth now exploring that other world. Imagine if those robots were us.

Thank you.

[The prepared statement of Dr. Friedman follows:]

PREPARED STATEMENT OF LOUIS D. FRIEDMAN, EXECUTIVE DIRECTOR, THE PLANETARY SOCIETY

Chairman McCain, Senator Hollings, and Members of the Committee:

Thank you for the opportunity to comment on the National Space Policy Directive issued two weeks ago by President Bush. Both its title, "A Renewed Spirit of Discovery," and its stated goal to "extend human presence across the solar system," capture a spirit that we at The Planetary Society have long advocated. The new Policy Directive states clearly that the human space program will no longer flounder without a compelling goal, and will finally set its sights on other worlds. Understanding and extending life beyond Earth is the only purpose that justifies the cost and risk of human space flight.

In the past much has been made of "manned" vs. "unmanned" programs—creating a sense of animosity between the human and robotic aspects of exploration. This is absurd—exploration requires sophisticated robots, no matter where the humans are, and, as humans, we are not satisfied with robots being our emissaries forever—especially when asking for popular support from a taxpaying public. We welcome the Policy Directive's up-front statement that the goal of the American space program is to "Implement a sustained and affordable human *and* robotic program to explore the solar system and beyond" (emphasis, mine).

Restoring exploration as the *raison d'etre* of the space program is a welcome development to those of us motivated by science and exploration.

The goal and vision are terrific. Setting goals and providing a broad vision are the President's job, and that of you and your colleagues. The challenge and question now is its implementation. Other space visions have turned out to be counter-productive to advancing space exploration, even with some noble aims: the shuttle, the space station, the 1989 "Moon-Mars Initiative," for example. A great deal of public, political and international constituency building will be required.

Cost and rationale are key to the constituency building, and these have not yet been adequately explained. Unfortunately, the Administration space policy study was conducted in secret; now there should be a period of public interaction. There is adequate time for this—the Administration's proposed first steps in the new policy are overdue and needed in any case to save our human space program.

Those welcome first steps in the implementation include:

- Retire the shuttle quickly after completing assembly of the International Space Station—2010 is mentioned as a target year. Redirecting the U.S. role in the space station to focus "on supporting the space exploration goal;"
- Separating crew and cargo, not just in launch vehicles but for "transportation to the International Space Station and for launching exploration missions beyond low Earth orbit;"
- Building a new crew vehicle that would "provide crew transportation for missions beyond low Earth orbit." Previous Orbital Space Plane requirements did not mention such missions.
- "Conduct robotic exploration across the solar system for scientific purposes and to support human exploration." This is particularly welcome—the policy is not limited to the moon and Mars, and supports science, even "to understand the history of the solar system."

The Planetary Society has previously advocated all of these.

These are the first steps—the ones that have to be funded and carried out in the five-year budget projections that the President will submit to Congress in a few days. We believe they are affordable and reasonable, and that worthy programs in space science would need not be cut to permit their accomplishment.

The questions and concerns about the Policy Directive are longer-term, beyond the five-year period. There are many open technical questions: the launch vehicles to be used for human flights to the Moon and Mars, the on-orbit assembly and propulsion requirements, the design of the interplanetary crew vehicle and dealing with weightless flight and the dangers of high radiation levels, setting up Mars infra-

structure support robotically, and the crew activity planning for Mars exploration. The program set out in the Policy Directive allow proper time for answering these questions, while at the same time accomplishing the first steps to redirect the program.

Funds for vehicles and human missions beyond Earth orbit are not yet allocated. The projected NASA budget may be inadequate for dealing with all the technical challenges and conducting human missions on the Moon or sending humans to Mars. But, ways to lessen the cost of human exploration of Mars, including from international partnerships, should also be learnt during this period. The Planetary Society urges that a Mars Outpost be set up robotically at a potential human landing site for emplacing robotic infrastructure that can increase reliability and safety and lower cost for the human mission. A Mars Outpost is an appropriate goal for international robotic Mars programs in the next decade.

Cost is determined by requirements. The technical steps cited above, and the emplacement of a robotic Mars Outpost, can reduce the cost of sending the humans to Mars. Conversely, Martian exploration will be more expensive if it includes extensive lunar objectives, prohibitively so if they include developing permanent lunar bases or open-ended exploration for speculative lunar resources.

Much rhetoric and even some of the official statements accompanying the Directive have been confused or misleading on this subject. One even called for launching spacecraft from the Moon into the solar system. There is probably no more expensive way that could be devised to reach Mars.

Fortunately, the President's policy itself does not call for these things. It says only that we should "Undertake lunar exploration activities to enable sustained human and robotic exploration *of Mars and more distant destinations in the solar system"* 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."* The underlined phrases clearly specify that lunar activities should be directed to enable Mars exploration, and not be an end in and of themselves.

Use of lunar resources for supporting exploration beyond the moon is proposed in a White House Fact Sheet that accompanied the release of the Policy Directive. The costs for any proposed use (*e.g.,* extracting oxygen from lunar rocks) must be estimated and compared with alternatives (*e.g.,* bringing the oxygen from Earth.) The topic must be subject to economic analysis before any commitment to such a program is made.

Twelve Americans have walked on the moon (15 more have flown around it) and some 70 robotic spacecraft have been there—we must carefully consider what we already have done there before planning new missions. The moon, as stated in the Policy Directive, shall only be "to prepare for and support future human exploration activities." We cannot afford to get bogged down on the Moon as we have in Earth orbit the past three decades.

While the United States and Russia have been to the Moon many times, it is a target of international interest. Currently:

- The European Space Agency has a mission, *SMART–1,* on the way to the Moon
- Japan is developing two lunar missions: *Lunar A,* which may launch in the next year, and *SELENE,* now scheduled for 2006.
- India is developing a mission, *Chadrayan-1,* for a 2008 launch
- There are reports from China they will conduct robotic lunar orbiter and landing missions in this decade, and perhaps that they have a 2020 human landing mission goal.

International cooperation is supported in the Policy Directive, and there is a need to build international partnerships for the grand goal of humans to Mars. Working with international partners can help us greatly to lower the cost of realizing our objectives at the Moon and in achieving the required set of missions faster. The Planetary Society urges the United States and other space-faring nations to cooperate and coordinate their robotic lunar missions. This could pave the way for an international human crewed mission to the Moon and be a solid step in building the team for the Martian expeditions.

Engineers can work out the details of interim technical milestones for a human mission to Mars. Various national and international studies have considered interim human destinations near Earth and at points where Sun and Earth gravity produce dynamical stability, or at asteroids, which provide interesting targets in their own right. These steps might also be investigated as interim milestones for human flight to Mars.

The Planetary Society cofounder, Carl Sagan wrote, "There's plenty of housework to be done here on Earth and our commitment to it must be steadfast. But we're the kind of species that needs a frontier—for fundamental biological reasons. Every time humanity stretches itself and turns a new corner, it receives a jolt of productive vitality that can carry it for centuries. There is a new world next door. And we know how to get there."

Only at Mars will we begin to learn whether humankind is limited to a single planet; only at Mars will humans be able to investigate the questions of other life. These are the great human purposes for which we send humans to space. The lure of Mars is dramatically revealed by the enormous public interest and excitement that attended the landings of Mars rovers this past month and the presence of five robot emissaries from planet Earth now explorating that alien world. Imagine if those robots were us.

Senator BROWNBACK. Very good, and a very provocative statement.

Dr. Lane?

STATEMENT OF NEAL LANE, UNIVERSITY PROFESSOR, DEPARTMENT OF PHYSICS AND ASTRONOMY, JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY, RICE UNIVERSITY

Dr. LANE. Thank you, Mr. Chairman. When I was in government, it was always a great pleasure to appear before this Committee, as it is today. It gives me an opportunity to thank you and the Members of the Committee for your strong support for science, for research, for education, and for space. It's my pleasure now to work with Senator Hutchison, in Texas. She's doing a wonderful job to emphasize the importance of science, research, and education in Texas.

I also am very appreciative of the chance to join this distinguished panel here to talk about the President's space plan. President Bush has outlined a space plan with three goals—complete the Space Station, build a new human spacecraft, and return Americans to the Moon by the year 2020.

So it's important to ask, I think, Are these the right goals? Is the plan, including the budget, likely to accomplish these goals? Well, I believe the Administration has three goals. And I would add a fourth, to strengthen NASA's world-class science and science education programs, including robotic exploration of space. These could provide a bold vision for the U.S. space effort.

Science has been much the heart and soul of NASA. The images and knowledge we've obtained from the Hubble Space Telescope and many other space-based telescopes have stunned astronomers, who are accustomed to spectacular images and discoveries.

NASA's planetary science missions have given us closeup images of even far-off planets and their satellites, asteroids, comets. And now the Spirit and Opportunity rovers soon will be strolling on the surface of Mars, sniffing around, looking for water, and making history.

NASA's programs to study our sun, its magnetic field, the solar wind of radiation that comes our way and creates the beautiful Aurora over Alaska and our northern states, provides important space weather forecasts that help us avoid the disruptions of communication that also result from solar activity.

NASA's satellite observations of Earth help us understand changes in land use, climate change, and weather prediction, and help protect us from natural disasters.

NASA also supports world-class laboratory research in its centers and its universities all across the Nation. This includes the unique experiments on the Space Station of the effects of zero gravity on human physiology.

Science must remain one of the highest priorities for the agency, in my view; and unless science is one of the principal goals of the new space initiative, then science will be relegated to the status of always in need of protection, as opposed to being enhanced. That would be a mistake.

So with science included, we have the makings of a bold vision, but a vision cannot simply be a dream. In order to be credible, it really must be achievable. So let's look at each of these goals.

Should we complete the Space Station? Without question, we should complete the Space Station, honoring our commitment to our international partners, as well as conducting the experiments and gaining experience that will be needed for trips out of Earth's orbit.

Should we build a new human spacecraft? Well, clearly it is essential that we modernize our fleet of human spacecraft. The space shuttle has been an extraordinary vehicle, but it is expensive to operate, and it still uses old technology. An important element of President Clinton's 1994 national space policy was to upgrade the shuttle, and design and build a new vehicle to replace it. The shuttle upgrade should continue, and it's time to get on with building a new vehicle.

Should we return humans to the Moon? Well, I think we should go back to the Moon, perhaps even spend some time on the Moon. The question is, when and how? When it is of sufficiently high priority for the American people to spend the money. And how, through expanded international cooperation, not only with our traditional partners in space, but with new partners, such as China or India, Brazil perhaps, and maybe others.

Should we enhance the NASA science programs? I've already spoke to this. I think without a rich portfolio of scientific research in centers and universities, and without robotic missions to launch new telescopes to monitor the health of the Earth and explore the surfaces of planets and satellites, our much more costly human spaceflight missions will be little more than precarious adventures.

Finally, is the budget adequate? Well, I think the President has described a bold plan. But he's not yet provided the architecture or the means. The 5 percent a year growth the President promises in the NASA budget certainly comes as a relief to an agency that has had many years of budget disappointment and has had to cut back important projects and programs. But the plan the President has described likely will cost much more than that, I think even in the early years. Thus, it is important for the Administration to lay out the estimated total costs and provide a roadmap to show the American people where we're going and what is it going to cost to get there.

Mr. Chairman, in my written testimony I raise a number of specific concerns by way of posing questions about all of these issues, but I will not repeat those here today.

So, in conclusion, I would support a real increase in the NASA budget if the science programs, including robotic exploration of

space, was strengthened and if the White House and the Congress—and let me emphasize, if the White House and the Congress—will support the necessary reorganization within NASA that will be required to begin the development of a plan to return humans on the Moon and beyond. It's not easy to reorganize an agency, and the Administrator is going to need all the help you can possibly give.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Lane follows:]

PREPARED STATEMENT OF NEAL LANE, UNIVERSITY PROFESSOR, DEPARTMENT OF PHYSICS AND ASTRONOMY, JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY, RICE UNIVERSITY

Mr. Chairman and members of the Committee: Thank you for this opportunity to testify on the future of space exploration, especially the policy implications of President Bush's proposal, outlined in his speech to the Nation on January 14, 2004, to return astronauts to the moon and expand human space exploration to Mars.

My direct involvement with matters of space policy was the time I served in the Clinton Administration, in the White House, as Assistant to the President for Science and Technology (the President's Science Advisor) and Director of the Office of Science and Technology Policy (from 1998–2001). Prior to that I was Director of the National Science Foundation (from 1993–1998), an agency that focuses both on research and on education. I am now at Rice University, where my position is University Professor, with appointments in the Department of Physics and Astronomy and as Senior Fellow of the James A. Baker III Institute for Public Policy, which includes space policy and other science and technology policy areas within the scope of its activities. Mr. George Abbey, former Director of the Johnson Space Center, is also a Senior Fellow of the Institute. The Rice Baker Institute has hosted an international summit on space policy and several other space events including workshops on space commerce. I also serve on the American Academy of Arts and Sciences Committee on International Security Studies, which is examining international rules on the use of space and implication of possible changes in the U.S. policy toward military uses of space.

The Vision of President John F. Kennedy

Rice University is where President John F. Kennedy gave his address on Sept. 12, 1962, in which he spoke these now famous words:

> "We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win. . . ."

The political situation in the world, forty years ago, was very different than it is today. The U.S. and USSR were in a face-off and on the brink of a nuclear holocaust. Sputnik, launched by the USSR in 1957, stunned the free world. On May 25, 1961, President Kennedy announced to a joint session of Congress that we would take Americans to the moon and safely return them to Earth by the end of the decade. Indeed, that mission was accomplished in just over eight years, at a cost of about $25 billion (1960 dollars), which is approximately $125 billion of today's dollars. This was an extraordinary accomplishment for NASA and the Nation. It launched the U.S. into the leadership position it enjoys today. Boys and girls visiting Challenger centers at the Houston Museum of Natural Science and other centers around the world, are still excited by the stories of the Moon landing and the vision of humans going back to the Moon and on to Mars.

Today, the USSR no longer exists. Russia is our partner in space exploration, and the hostile threats to our Nation no longer come from a single powerful nation.

It is ironic that on November 14, 2001, at Rice University, nearly four decades after President Kennedy's speech, Russian President Putin gave a speech in which he said: "We have (for) a long time been cooperating in (the) space exploration field. And the creation, the establishment of the International Space Station is 85 percent percent (a) bilateral Russian-American project."

The U.S. Human Space Flight Program

The U.S. human space flight program—from John Glenn's heroic Mercury flight in February of 1962 to the Gemini missions and Apollo moon landings to the development of the Space Shuttle program and construction, with Russia and other international partners, of the International Space Station—has been one of America's greatest stories of adventure and discovery. Once again this country showed the world that the American pioneering spirit and passion for exploration can cause people and nations to do extraordinary things. The benefits are not only in gaining a better understanding of how humans can live in space, but the engineering and technological advances that provide totally unanticipated benefits for people, our economy, and the Earth's environment.

Human exploration of space is not without risk to the courageous men and women who make the journey. Along with the triumphs of our human space program we have suffered great tragedies—*Apollo 1, Challenger,* and more recently, *Columbia,* where astronauts gave their lives for the Nation. We must do everything possible to make sure our astronauts and their partners from other nations are as safe as they can possibly be in space and that the irreducible risks are made clear to them and to the public.

Scientific Accomplishments

As exciting as human space flight may be, the U.S. civilian space program is very much about scientific exploration and discovery, using robotic means. NASA has often carried out unmanned space science missions in cooperation with international partners; but it has played the leading role in many of the most important ones.

The robotic studies of our solar system have produced a revolution in scientific understanding of our sun, planets, asteroids, comets and of the Earth's immediate environment. Spectacular discoveries, including photographic images of the moon (Ranger, Surveyor, Lunar Orbiter, Clementine); Mars (Mariner, Viking, Mars Observer, Mars Global Surveyor, Mars Pathfinder, Mars Exploration Rovers Spirit and Opportunity); Venus (Mariner, Pioneer, Magellan); Mercury (Mariner); outer planets (Pioneer, Voyager, Galileo, Cassini); asteroids (Clementine, NEAR), comets (Stardust). Other missions are giving us new knowledge about the Sun (SOHO, Ulysses, HESSI, TRACE), its radiation and solar wind (Genesis, GEOTAIL, Polar) and the "space weather" problems it can cause on Earth and the plasma environment nearby (Cluster, IMAGE, WIND); and the Earth's upper atmosphere (TIMED). Voyager 1 and 2 (now 26 years old) are probing the outer reaches of the solar system.

Joining the successes of these past and ongoing studies of the solar system is an extraordinary record of research and discovery in astronomy and astrophysics. An array of NASA space-based astronomical telescopes (Hubble, Compton, Chandra, ACE, GALEX, HETE–2, IMAGE, RXTE, SAMPEX, Spitzer, SWAS, WMAP, XMM Newton), several built and operated in cooperation with the European Space Agency and nations around the world, complement ground based telescopes (*e.g.,* the Keck telescope and Gemini telescopes and others supported by the National Science Foundation). NASA, with its partners, has over 20 telescopes under development and an even larger number under study. In addition to building and operating these space-based observatories, NASA is a major supporter, along with the National Science Foundation, of basic research in astronomy and astrophysics at major universities all around the country.

Closer to home is NASA's Earth Science Enterprise, which launched its flagship Terra in December of 1999, and operates (or has scheduled launch dates for) over thirty Earth observation satellites, many in cooperation with other agencies and countries, to provide images and data on many aspects of the Earth's atmosphere, ocean and land. These include observations of: atmospheric temperature, moisture content, clouds, precipitation (Aqua), aerosol cloud properties (CALIPSO), absorption and re-emission of solar radiation by the Earth (ERBS), imaging and sounding data to help weather forecasting (GOES–L and M), soil moisture and freeze line (HYDROS), atmospheric carbon dioxide (OCO), global ocean currents (TOPEX/Poseidon), and other missions that provide information useful in understanding climate change and improving weather prediction.

In addition to the high-profile science research activities in Astronomy and Planetary and Earth Science, NASA supports important research in the biological and physical sciences, including research related to the National Nanotechnology Initiative.

One area of the life sciences that is particularly important for human space flight and that requires humans to live in space is studying the long term effects of zero gravity on the human body. We will not be able to make journeys to Mars, or even to stay for awhile on the moon, until we understand how humans respond and can insure their continued health. NASA has formed an excellent partnership to imple-

ment that research with the National Space Biomedical Research Institute (NSBRI) that brings together a number of the Nation's finest life science research institutions, under the leadership of the Baylor College of Medicine, to further our understanding of the effects of space travel on the human body.

Science is at the heart of NASA and the U.S. effort in space exploration and discovery. Any considerations of a change in national space policy should insure the continued health of NASA's science programs. But, before we talk about changes in space policy, it is important to reflect on where we have been.

U.S. National Space Policy

President Clinton established a National Space Policy early in his Administration that emphasized the construction of the International Space Station, the first component of which (Zarya) was placed into orbit in November of 1998, followed by the first U.S. component (Unity), delivered by the Shuttle, in December of that year. The Clinton Administration also worked to provide funding for NASA to make an "end of the decade" decision on a replacement for the Space Shuttle, to continue robotic explorations of Mars, and to support a robust program of Astronomy, Space, and Earth Sciences. With regard to the Space Station, President Clinton made the decision that Russia would become a key partner, so that we could take advantage of their enormous experience in space, including the MIR space station, and Russia's technical skills. It is a partnership that has had its 'ups' and 'downs', largely because of the economic situation in Russia, but today it is clear that we would not have the Space Station had it not been for this vital partnership.

President Bush's Plan to Return to the Moon and Beyond

President Bush, in his speech of January 14, described a bold plan that will take humans back to the moon by 2020, with the expectation that humans would then go on to Mars, sometime in the distant future. In particular, the President described three goals:

(1) "complete the International Space Station by 2010";
(2) "develop and test a new spacecraft by 2008 and to conduct the first manned mission no later than 2014";
(3) "return to the moon by 2020, as the launching point for missions beyond."

The President said that the first part of this program would be funded by adding $1 billion to the NASA budget, spread out over five years, and reallocating $11 billion from within the NASA budget during the same timeframe. These amounts are within the annual 5 percent increase the President plans to make to the NASA base budget (approximately $15 billion), starting in FY 2005. The President has named a new Commission, chaired by former Secretary of the Air Force Pete Aldrich, to advise him on implementation of the new vision.

President Bush has laid out a bold vision for the human space program and a rough time frame for making progress. The American people need a vision in order to share in the excitement and support the costs of the national space effort. NASA also needs a destination, compass heading, and time frame for human exploration of space so that it can plan and manage effectively as well as log its progress. Such a vision, however, has to be achievable to be credible, so it is important to be aware of all that is involved in accomplishing the President's goals, if those are the right goals for the country.

There are two overarching questions one might ask: Are these the right goals? Is the plan—including the budget—likely to accomplish these goals?

I will briefly comment on the three goals, add a fourth "science" goal that, in my opinion, is at least as important as the others, and suggest a number of questions that I hope the Commission, Administration, and Congress will consider carefully.

International Space Station

The goal to complete the International Space Station is not only appropriate but, in my view, absolutely essential. Our commitments to international partners must be met if we are to maintain any credibility in space cooperation. We are not always viewed as a reliable partner in such endeavors and often our political will is questionable. While there was criticism by some members of Congress of President Clinton's decision to bring in the Russians as a key partner in building the Station, clearly it was very important to do so. Not only did Russia provide outstanding technical expertise and hardware and unprecedented experience with humans in a space environment (on space station MIR), Russia was also able to respond quickly to our need to bring back those stranded on the Station by the grounding of the Shuttle fleet, following the tragic *Columbia* accident, and to continue a rotation of crews so the Station can remain in operation. A second reason to complete the Space Station

is to continue to gain experience with humans in space and to develop new technologies and systems that, along with the planned Shuttle upgrades, will be needed in developing a new Crew Exploration Vehicle and moving beyond low earth orbit. But, the Space Station is not finished and still presents many challenges. Our intentions, our commitment and our priorities must be clear.

Is our commitment to complete the Space Station simply tending to unfinished business, or do we still consider the Space Station and the scientific experiments we will do there among our highest priorities in human space exploration? What is our commitment beyond the construction of the Station—are we simply leaving it to our international partners to operate, while we move on to more exciting things?

New Spacecraft—The Crew Exploration Vehicle

The Space Shuttle has performed far better than its early critics predicted. That is because an enormous amount of human attention is given to keeping the Shuttles flying and the talent and skills of our astronauts. While I was in the White House, I had the privilege of visiting Johnson Space Center and observing a Shuttle Commander and Pilot going through mind-boggling malfunction scenarios on the Shuttle simulator. I came away very conscious of how good these men and women are, but also with a better appreciation of the complexity of the Shuttle, which still relies on old technology, and the very real risks to flying it. The Shuttle technical upgrades, begun in the previous Administration, are very important and should be carefully considered by NASA and the Commission as various options are examined. These upgrades have been planned not only to improve the safety and reliability of the Shuttle but also to develop new technologies and systems for future spacecraft and missions beyond Earth's orbit. Future upgrades could include replacing solid-fuel by liquid-fuel boosters, which (flown without the Shuttle) could be important for lunar or Mars missions.

The design of the Crew Exploration Vehicle (CEV) appears to be a work in progress, the intended outcome of the "spiral approach" described by the NASA Administrator. Whatever may be the detailed design, we will need a heavy-lift capability for humans and cargo. Today, the Shuttle is our heavy-lift vehicle and can carry 60,000 lbs, currently the largest payload of any of the world's vehicles. It also has the capability to return heavy cargo to earth, a unique capability that will be greatly needed by the year 2010. Many favor the idea of a human spacecraft, *e.g.,* the CEV, being launched on an expendable launch vehicle (ELV). We have no such human-rated rocket today. The CEV presents many challenges.

How will NASA insure that safety of the astronauts remains the top priority for the human space flight program during a time of substantial realignment of programs, reallocation of funds, and reorganization of personnel, and properly implement the recommendations of the Columbia Accident Investigation Board, chaired by Admiral Gehman? Does NASA plan to carry out the planned Shuttle upgrades and, if not all of them, which ones and on what schedule? What is NASA's future plan for providing heavy-lift (down-mass as well as up-mass) capability? What are the arguments in favor of the plan to abandon the Shuttle four or more years before a new human spaceflight capability is in place and what are the risks? What are the arguments for and against, and tradeoffs in capability and cost, of choosing an entirely new spacecraft architecture as opposed to an architecture that makes use of a modernized Shuttle?

Return to the Moon—and Beyond

Should we go back to the moon? My answer is yes! The question is when and how? Returning to the moon must be of sufficiently high priority for the Nation to justify the expenditure of the large amounts of money required, rather than using the funds to meet other vital national needs in many areas that impact the quality of life of people living on Earth—education, economy, energy, health, environment, security. Moreover, the most important "how" question is the extent to which this will be an international effort involving not only our traditional partners in space (countries of Europe, Japan, Canada and other nations that are contributing to the International Space Station), but also new space partners like China, India and Brazil. The window of opportunity to use cooperation in space to avoid conflicts in the future may not be open long; and this is an opportunity that must not be missed.

The NASA Administrator, in his comments to the press, emphasized that this is "very much going to be a U.S.—led endeavor . . . to achieve this set of American, U.S. exploration objectives." But, international cooperation, including Russia being placed on the critical path, has been vital to the success of the U.S. space effort.

There are many obstacles to international cooperation, including: export controls (which have seriously damaged our commercial satellite industry); the effects of the

Iran Nonproliferation Act of 2000 on U.S.-Russia cooperation; and denied access to foreign students, scientists, and engineers, whom we need today in order to advance our programs in space and other technical areas. This need will only grow in the future. Without question, the U.S. must protect its citizens from attack by terrorists or other hostile forces. But, this must be done in such a way that does not damage the Nation's technical capability.

There is also reason for other nations to question U.S. policy on the future use of space, given statements made by high-level U.S. government leaders and in military strategy documents about the need to prepare for increased military activities in space. The American Academy of Sciences Committee on International Strategic Studies is carrying out a study of the technological, commercial, and political implications of U.S. policy in space, and of rules and principles for protecting a long-term balance of commercial, military, and scientific activities in space. I encourage the Administration and Congress to invite information on this important study as it may impact your decisions on future space policy.

How will the Administration insure that other nations—Russia, our European and Asian partners, perhaps China and India—are seriously engaged in the planning and realization of the President's vision, indeed that they are able to share that vision? How will the U.S. assure the rest of the world that we continue to hold the view that space should be used for peaceful purposes?

Scientific Research and Education

Mr. Chairman, I would add a fourth goal that I consider to be at least as important to our space policy as the President's goals:

> Insure that the United States remains the world's leader in scientific and engineering research and in educating young people for careers in science, engineering and technology.

Unless the Nation has a deep understanding of physical and biological nature—on and off our planet—we will not be successful in exploring space frontiers with robots or humans. Unless we attract more young people to science and engineering, and give them a solid education, we won't be able to do the science or the exploration.

Perhaps the greatest challenge for our space program is finding the talented people—scientists, engineers and other technical professionals—who will be needed to accomplish a bold space agenda for the Nation. Careers in science and engineering are not as attractive to young people as they once were; and we are having a harder time attracting and retaining talented individuals from abroad. Universities where scientific and engineering research is strong are particularly important in addressing this technical workforce issue. I believe history has shown that the continued Federal investment in university research and graduate education is money well spent.

NASA emphasizes that the Administration's new program is primarily not about science, but about human exploration. But, science has been one of the most important successes of the U.S. space program. New scientific knowledge as well as revolutionary technologies have been the tangible products of the Nation's investments in space and are key to NASA's accomplishment and well-deserved reputation for excellence throughout the world. It is vital to NASA's future that the science not be given lower priority in the new program. There are many important scientific facilities and robotic missions already planned and others not yet conceived. These unmanned missions are by far the most cost effective way to do science. My concern is that money needed for human space exploration will erode the science budgets, especially given the need for substantial reallocations of money within the NASA budget. The words science and exploration are easily confused in most people's minds. The rationales for the Shuttle and the International Space Station were never primarily about science, but I don't believe that message ever got through to the public.

There are examples where human exploration of space and science go hand-in-hand. Study of the effects of zero gravity on human physiology is one obvious example. Also, humans in space can be called upon to do things that otherwise would be very difficult, *e.g.,* the successful repair and upgrade missions to the Hubble Space Telescope. It is disappointing that a decision has been made to terminate the enormously successful Hubble Space Telescope, and a planned servicing mission has been cancelled. I believe this decision ought to be reconsidered.

I would ask the following questions:

> How will NASA and the Administration insure that the exploration goals of the moon-moon proposal do not cut into the science goals for NASA programs and those of other agencies? If NASA science missions are to be directed toward the

goals of the moon-Mars proposal, does that mean that missions given higher priority by the science community will have lower priority by NASA? How was the Hubble cancellation decision arrived at and what was the rationale for that decision? How will NASA help the public to better understand the differences and connections between human space exploration and science and the rationales and best approaches for doing both? How will NASA strengthen its partnership with universities to support academic research and help recruit more scientists and engineers?

The Budget

Turning now to the second of the two overarching questions I posed earlier: Is the plan—including the budget—likely to accomplish these goals?

The President has proposed 5 percent increases each year for the next five years. Given the size of the current and future projected deficits, proposing a modest growth budget is understandable. Indeed, following many years of disappointing budgets, 5 percent is good news for NASA. But, I believe the expectations raised by the President in his speech, far exceed the proposed budget for this ambitious program, even for the early stages of the plan. What the President has proposed implies a major reorganization, even change in culture, of NASA and its centers.

The history of our space program has shown that coordination of activities across NASA centers and with industry remains very challenging. Significant reallocation of resources is met with strong resistance, often with the help of friends in Congress. Reorganization of NASA is probably long overdue. Furthermore, the NASA budget, especially the science budget, is severely earmarked in ways that usually do not address the agency's top priorities and certainly limit the management flexibility of the Administrator. It will be impossible for the NASA Administrator and his NASA colleagues to make the necessary changes unless the White House and Congress support them fully.

But, even with the best intentions and dedicated hard work of the Administrator and his talented NASA team, these budgets will appear to most of America, including the U.S. space industry, and to the world as 'business as usual'. Unless the U.S. space plan is realistic, unless the Administration matches its rhetoric with estimated overall costs and an adequate budget, a false promise could do harm to our space efforts, dash the expectations of girls and boys who decide to become scientists and engineers in order to be a part of an exciting future in space, and seriously damage our credibility as the world's leader in space exploration and science.

I strongly urge the Administration and Congress to work together to look at several out-year budget scenarios and compare the objectives and milestones—for human exploration and for science—under each. It may well be that the Nation has the capacity, given sufficient funding, to make progress at a much faster pace than the plan has proposed, especially with serious international engagement and cooperation and making use of decades of NASA's experience, R&D, and promising new technologies and systems ready to be employed. It may be that the risks of terminating the Shuttle program before having an alternative means to put humans in space are too great to justify this step. There are likely to be *scientific* opportunities on the horizon that are so compelling that they will warrant additional funding. Thus, developing accurate cost estimates and corresponding objectives and milestones for various phases of the initiative along with a transparent set of agency priorities is essential. There are several questions one might ask:

What are the estimated total costs of completing the construction of the Space Station and annual operating costs beyond that; the development, testing and commissioning of the new Crew Exploration Vehicle; robotic missions in preparation for a return to the moon; and the first human return to the moon and back? How will the $11 billion be reallocated within NASA's budget? What changes will be made to the rest of NASA's programs, especially the science programs, and with what levels of funding? What are the estimated costs of funding Russian or other non-U.S. flights to the Space Station after the Shuttle is phased out?

Conclusion

Mr. Chairman, I believe that the three goals outlined in the current Administration's space plan are ambitious and worthy of serious consideration. And, as I have indicated, I would add a very important fourth goal: to strengthen NASA's science program. However, the architecture of the President's plan and overall cost have not been provided; and the five-year budget proposed to begin to accomplish these goals, in my opinion, is unrealistic. Hence, the Administration's commitment rings hollow, inviting cynical criticism of the seriousness of the plan from our international space partners and from the American public as well. It is disappointing that two weeks

after the President's speech on space, none of the words "space", "exploration", or "science" appeared in the President's state of the union message.

The nation needs to be clear about why we have humans in space. We need a renewed vision and serious plan for space, especially as our Shuttle fleet continues to age and as we complete the International Space Station. But, that vision must be more than a dream. The President has provided a part of a vision; but he has not provided the architecture or the means.

I would support real increases in the NASA budget, perhaps even larger than 5 percent per year. But along with that growth, NASA must be held accountable for the major reorganization that will be required and protection of its scientific programs, that are so important to the future of the Nation. And the White House and the Congress will need to support the efforts of the NASA Administrator to do those things.

Therefore, Mr. Chairman, I commend this Committee for holding these hearings, listening to a wide range of views, and working with NASA, the Administration and other in Congress to insure that we do not miss this window of opportunity to move the Nation into a bold new direction for space science and human exploration of space.

Thank you, Mr. Chairman.

Senator BROWNBACK. Thank you, Dr. Lane.

Dr. McCurdy, welcome.

STATEMENT OF DR. HOWARD E. MCCURDY, PROFESSOR OF PUBLIC AFFAIRS, AMERICAN UNIVERSITY

Dr. MCCURDY. Mr. Chairman, thank you for the opportunity to come before the Committee and share my insights into NASA, as an institution.

If this initiative is taken seriously, it will have a transforming effect on NASA, as an institution. To put that in context, think of the situation that existed in May 1961, when President John F. Kennedy set out the goal of landing humans on the Moon, returning them safely to Earth, and doing that by the end of the decade. At that time, there wasn't anybody in NASA who knew how to do it. NASA lacked the capacity to manage large projects. They didn't have the necessary technology. They didn't have the infrastructure. They didn't have the personnel. And yet, 8 years later, Americans returned safely from the Moon. In a similar sense, this event challenges NASA in deep and profound ways.

Can it be done? Well, in theory, yes. Think of the *Apollo* objective in this way. The Apollo objective had not just one objective, but two. The first was to accomplish the technical objective of taking humans to the Moon and returning them safely. But the Administration and the Congress also imposed a second requirement, that it be done within 8 years, a severe schedule constraint that led to all sorts of technological advances and decisions within the space program.

Now, in a similar way, this objective asks NASA to do two things. It asks NASA to send humans and robots to the Moon and Mars, not on a schedule this time, but within severe cost constraints; in essence, to do it for about what the agency receives today in its annual budget. In the 1960s, NASA was able to accomplish the twin goals of reliability and schedule. And now it's being asked to accomplish the twin goals of reliability and cost.

Is NASA, as presently constituted, capable of doing this? In my opinion, it is not; at least not on the human spaceflight side. This will be a transformational event for NASA if it carries it out. NASA has suffered terribly over the past 30 years from the drift that's

been imposed on the human spaceflight program. And you can also learn, by examining the work of the Columbia Accident Investigation Board, that there are difficulties within NASA's human spaceflight culture. It's not the same agency that existed in the 1960s. So these are things that will have to change in order for NASA to be able to do it.

Do the seeds of this reform exist within NASA? Well, I think they do, historically, but there's no guarantee that they're likely to grow and flower, in two areas in particular. First, there is still the memory of the *Apollo* years and the techniques that were used at that time. And, second, great advances have been made in the robotics programs over the last 30 years. We're not just going to learn, from the robotics program, how to fly machines; but we're going to learn, from the robotics program, how to manage programs that are low cost.

Consider this. The current Spirit/Opportunity Mission Mars is costing one-fifth of what we spent to send two Viking landers to the surface of the planet in 1976. Great advances in technology have been made, but also great advances in organization.

So I would suggest to the Congress, if you're asking the question, "What can you do to help NASA make this transformation," that as much as possible, you learn from that experience and impose it on NASA. I'll give you a couple ideas, and there's more in my written testimony.

One, make cost a goal. Make it a goal in the same sense that President Kennedy made schedule a goal in the 1960s. We know, from the robotics program, that when NASA has such goals, it can hold to them and accomplish them. That's been proven with Spirit, with Opportunity, with Pathfinder, near-Earth asteroid rendevous, and other areas, as well.

Second, restore NASA's in-house technical capability. This may mean much more extensive in-house construction of spacecraft. Frankly, good scientists and engineers don't stay sharp by monitoring government contracts; they stay sharp by working on the hardware itself.

I'd also suggest that you look to the robotics programs, and also to areas in private industry where industrialists and government employees have developed very small teams that are able to complete complex projects under severe cost constraints. It's not necessary to recreate Project Apollo. Project Apollo worked because NASA imported, from the U.S. Air Force, techniques known as systems management. In the same way, if it's going to make these new initiatives work, they will need to import, from industry and from their own robotics and space science areas, low-cost techniques that have been developing over the past 10 to 20 years. There is an experience base there.

So can NASA do it with its present organization and institution? I think not. But does history give us confidence that it could transform itself in such a way that this would be possible? And I think that's true. If, 20 or 30 years from now, humans stand on Mars, and robots with them, NASA will no more resemble the institution that exists today than the NASA of 1969 resembled the NASA of 1961.

Thank you.

[The prepared statement of Dr. McCurdy follows:]

PREPARED STATEMENT OF DR. HOWARD E. MCCURDY, PROFESSOR OF PUBLIC AFFAIRS, AMERICAN UNIVERSITY

I am not here to give my personal views on the desirability of undertaking the space flight initiatives set out in the president's speech on January 14, 2004, refocusing the purpose of the Nation's human space flight activities. Rather, I will comment on whether the National Aeronautics and Space Administration (NASA) as presently constituted is capable of carrying out that initiative.

In my judgment, based on eighteen years of studying NASA's organizational practices, it is not. The practices associated with human flight over the past decades have left NASA ill-prepared to undertake a focused exploration program, especially one that addressess the cost constraints imposed by the president's directive. Yet this need not cause despair. NASA employees have overcome similar difficulties in the past and Congress can encourage them to do so again in the future.

In essence, my message is one of cautious optimism. Accomplishment of the mission is not possible with the NASA that exists today, but the fact that the agency has transformed itself in the past encourages us to believe that transformation can occur again.

Why NASA is Not Prepared

For thirty-four years, a succession of leaders in the field of space exploration have called upon public officials to give NASA purpose and direction. As a science and engineering organization, relying upon project management techniques, NASA works best when the people implementing national space policy have a clear vision of their ultimate objective, the time available to accomplish those objectives, and the various constraints such as cost under which they must operate.

From 1961 through the landings on the Moon, the human space flight program operated under such mandates. The purpose and timetable established in President John F. Kennedy's May 25, 1961, speech provided focus for America's civil space effort and imposed discipline on the new space agency.

As Americans prepared for the lunar landings, NASA officials and other government leaders proposed to extend Kennedy's vision. Much like the current initiative, they called for a post-Apollo space effort focused on the moon and Mars, bolstered by an energetic space science program. The report of the Space Task Group was presented in September, 1969, followed in later years by a succession of reports calling for much the same thing. In March, 1970, President Richard Nixon rejected the report of the Space Task Group, thereby initiating three decades of drift in which leaders of NASA's human space flight program were obliged to operate without long-term focus and direction.

In response, leaders of the space community adopted an incremental approach to human flight. They pursued elements of their long-range vision in succession, one at a time, without reference to an overarching goal. First they sought to complete a reusable space shuttle, originally conceived as a means of transferring people to and from an Earth-orbiting space station. Then they started work on the space station. As the date for declaring the space station "core complete" approached, NASA officials requested permission to pursue the next logical step in their long-remembered but never-approved long range plan.

Thirty years of incremental drift have had a dysfunctional effect on NASA's human space flight effort. Without a long-term goal to provide purpose for new human flight initiatives, NASA officials and their supporters have been obliged to create broad political coalitions as a means for getting new initiatives approved. The programs emerging from these coalitions have contained so many objectives that NASA officials have accomplished few of their specific goals.

The NASA space shuttle, for example, was designed among its many objectives to carry people to and from an Earth orbiting space station, transport the components of that station to space, serve as a "space truck" for commercial payloads (some carrying upper stage rockets attached to payloads headed for geosynchronous orbit), deliver military reconnaissance satellites, deliver and repair (and possibly return) space telescopes, and serve as a short-duration micro-gravity research laboratory. The shuttle fleet had to be reusable, capable of launch up to 50 times per year, and cut the cost of launch operations to about $10 million per mission.

As members of the *Columbia* accident investigation board observed, the existence of so many conflicting objectives severely compromised NASA's ability to build a safe and reliable vehicle. "The increased complexity of a Shuttle designed to be all things to all people," board members wrote, "created inherently greater risks than if more realistic technical goals had been set at the start." The most serious mistake that

NASA officials made in developing the vehicle dealt not with the design of any particular component, "but rather with the premise of the vehicle itself." (CAIB report, p. 23)

NASA officials undertook a similar approach to the design of the International Space Station. They appealed to astronomers, people interested in space science, advocates of a return to the Moon, commercial interests hoping to manufacture micro-gravity products, communication satellite companies, international partners, and the U.S. military. Early space station designs included hangers for satellite repair, micro-gravity research laboratories, mounts for observational instruments, pallets for scientific instruments, and two large keels within which large spacecraft bound for deep space missions could be prepared. Further confounding these objectives, NASA officials estimated that they could develop such a multi-functional facility for only $8.8 billion.

Space station advocates learned that the political coalitions necessary to win approval for such initiatives were much easier to construct than the actual facilities. While attractive for building political support, the various station functions proved technically incompatible and impossible to develop within the proposed cost. As a consequence, NASA officials spent the entire ten years set for construction of the station (1984–1994), as well as the $8.8 billion cost estimate, redesigning the facility and reducing its scope.

For thirty-four years, officials in the human space flight community have urged political leaders to adopt long-range space goals. Yet NASA officials during this period grew accustomed to the practices necessary to operate in an objective-free atmosphere. The effect of this cultural shift was readily apparent in the agency's response to President George H. W. Bush's 1989 proposal for a human Space Exploration Initiative focused on the Moon and Mars. Following the proposal, White House officials directed NASA to prepare an enabling plan. The study that agency leaders produced disappointment. To people outside NASA, the study seemed more like an exercise designed to protect existing agency programs and restore the health of ailing field centers than an opportunity to renew the long-term vision of space.

NASA officials treated the Space Exploration Initiative as a healing balm, an ointment applied to the institutional members as a means to get well again. If NASA officials take a similar approach to the current Mars initiative, with its severe cost constraints, it will produce a similar result. The initiative will certainly die.

During the period of institutional drift, NASA underwent additional changes that similarly compromised its capability to carry out complex human space flight activities in a reliable way. These alterations are well documented in the reports of the presidential commission that investigated the space shuttle *Challenger* accident and the Columbia Accident Investigation Board. Briefly stated, the reports concluded that NASA's organizational culture had changed in detrimental ways. The agency had gone from an institution capable of meeting its goals to one in which human space flight officials struggled to achieve reliability, cost and schedule objectives which the agency operated.

Cultures consist of the assumptions that people make as they go about their work. As a illustration of how much the NASA human space flight culture has changed, consider the follow point. NASA officials and their contractors in the early decades of space flight operated under the assumption that the agency would not launch a spacecraft until its designers could prove that they were ready to fly. In both the *Challenger* and *Columbia* accidents, NASA officials required concerned individuals to prove that spacecraft were *not* ready to fly (or land) in spite of visible safety concerns.

Organizational practices such as these take root over many decades. Similarly, reforms require many years to become imbedded in the minds and habits of agency employees. Organization cultures take a long time to change. They deteriorate slowly and they revive themselves only after lengthy adjustment periods.

Hope From History

Confrontations with reality need not be a source of despair. In fact, the first step toward institutional recovery consists of acknowledging the situation as it exists. NASA's human space flight effort has existed without focus and discipline for more than thirty years, leaving a legacy that will be difficult to change. Yet this is not impossible. It has happened before and it can happen again.

In the Spring of 1961, when President Kennedy challenged Americans to race to the Moon, NASA was totally unprepared to carry out the mandate. Congress had created NASA three years earlier by melding the research laboratories within the National Advisory Committee for Aeronautics (NACA) with agencies like the Jet Propulsion Laboratory and the Army Ballistic Missile Agency (ABMA). People from component agencies had great technical skill, but absolutely no experience man-

aging activities on the scale of Project Apollo. They were accustomed to managing small research projects, not large-scale operations. The institutional habits of people who had inhabited the forty-three year old NACA were well set, as were the practices of employees working within the ABMA under Wernher von Braun's rocket team.

NASA officials at that time did not understand how to manage large programs. They did not have enough people; they did not have enough money. Existing field centers were independent and uncooperative. The United States lacked the technology to fly to the Moon. No American astronaut had ever flown in orbit, much less engaged in rendezvous and docking. No one knew how to get to the Moon and back. Leading strategies such as Earth Orbit Rendezvous and Direct Ascent were either technically infeasible or impossible to complete by the decade's end. When he made the suggestion that the agency concentrate all of its resources on accomplishing the lunar goal, NASA's head of human space flight was fired for what was then viewed as intemperate remarks.

Yet eight years Americans returned safely from the Moon. During those eight years, NASA reorganized itself twice, forcing the leaders of previously independent field centers to submit to a central coordinating office in Washington, D.C. To oversee Project Apollo, NASA officials imported management experts from the Air Force ballistic missile program, the primary repository of people who understood large-scale systems management. NASA employees and their contractors perfected new technologies, such as hydrogen-fueled rockets and orbital rendezvous. They revised organizational procedures after the loss of three astronauts in a space capsule fire during a launch center ground test, a critical exercise in institutional learning. Like the current Administrator, the person who oversaw NASA during this period was an expert in management and finance. Neither an astronaut nor an engineer, James Webb was a budget director and President of the American Society for Public Administration.

President Kennedy's May, 1961, speech was a transforming event. It transformed NASA from an agency of technical experts into an institution capable of implementing extraordinarily complex space flight activities. The lessons learned through human space flight quickly spilled over onto the space science side, where individuals carried out the great planetary and space telescope missions of the decades that followed.

Recently, NASA has transformed its space science activities. Space scientists have not suffered through the same drift that afflicts human space flight activities. Space science missions have been focused; objectives more apparent. Technology advances in areas such as imaging and automation have occurred. New management techniques have been perfected, some significantly different than the large-scale systems management practices that propelled the success (and the cost) of Project Apollo.

Consider this fact as an illustration of the transformations occurring in space science. Stated in the inflation adjusted value of today's dollars, the 1976 Viking mission to Mars cost $4 billion. For that sum, NASA successfully placed two landers on the surface of Mars. The Mars Exploration Rovers that arrived this January, 2004, are carrying out their missions for $820 million. Even acknowledging that funds for Project Viking also purchased two orbiters (total cost in today's dollars about $800 million), the difference is dramatic. NASA space scientists have learned how to fly for a fraction of the cost of previous endeavors, using technologies that have advanced enormously.

In searching for the means to mobilize an aggressive exploration program on Mars, NASA officials can turn to themselves for the necessary experience. The lessons exist within the agency, both today and historically. The Apollo flights to the Moon cost $25 billion in the currency of the time. That translates into a total cost of approximately $175 billion today. During the 1960s, NASA officials were told to achieve reliable space flight in a crash program with an impossibly tight schedule. For the current initiative, government leaders propose to loosen the schedule and the milestones associated with it, but to operate under severe cost constraints. In practical terms, NASA officials are being asked to fly reliably to the Moon and beyond for a fraction of the cost of Project Apollo.

On its face, the task may seem impossible. Nonetheless, NASA officials have encountered similar challenges in the past and prevailed. They overcame analogous difficulties in the 1960s and they have achieved low-cost innovations in their robotics and space science programs.

Lessons for the Future

Although NASA employees are allowed a great deal of technical discretion in carrying out space flight programs, they do not operate in a vacuum. They respond to the nature of national space policy and the guidance they receive from Congress and

the White House. The transformation of NASA's human space flight activities will require a number of important changes, ones that can be encouraged by congress and the executive. In general, transformation will require NASA to become more like the agency that sent Americans to the Moon and robots to Mars and less like the agency that fumbled the development of the space shuttle, International Space Station, and Space Exploration Initiative. It will require the installation of cost discipline, the resurrection of a culture of reliability, the restoration of discipline and focus, and the merging of robotic and human capabilities. These will be major changes, wide in scope and particular in detail.

To encourage the transformation of NASA, members of Congress might consider the following practices.

1. Be very clear about goals. Mission ambiguity and wiggleroom are the enemies of discipline and focus within NASA. For example, the mission as contained in the presidential directive does not seem to include a lunar base as an intermediate step to Mars. The moon is to be used only insofar as it contributes to the exploration of Mars, as a test bed or proving ground for deep space technologies. Additionally, the purpose of the program is not to land humans on Mars. Rather, the purpose as expressed thus far is the exploration of Mars using humans and robots. Experience tells us that the optimal mix of robotic and human flight technology is likely to change significantly as the mission evolves, discouraging a definition that presupposes a specific role for humans in advance.
2. Make cost constraint a mission goal. During Project Apollo, meeting the "end of the decade" deadline imposed an objective as important to the definition of mission success as landing astronauts on the Moon and bringing them safely home. The deadline repeatedly served to focus attention on necessary tasks; it strongly influenced technical decisions such as the one to engage in "all up" testing of the Saturn V. In NASA's robotic and satellite programs, cost constraint has risen as a mission goal to a place commensurate with science objectives. NASA employees have repeatedly demonstrated that they can achieve multiple objectives—reliability plus cost or schedule goals—so long as those objectives are clearly stated.
3. Restore in-house technically capability to the human space flight program. NASA's secret weapon for completing Project Apollo arose from a combination of strong in-house technical capability with systems management techniques imported from outside. Many people agree that NASA has lost too much of its in-house technical capability, especially for human space flight. Agency employees who spend most of their time monitoring contracts cannot maintain the technical edge necessary to explore Mars. To produce outstanding results, they need to work with flight hardware. This has been demonstrated repeatedly in both the human and robotic flight programs, most recently within the Mars exploration effort. Successful missions, such as Pathfinder, have been led by persons with extensive "hands on" knowledge of spacecraft components. Experience suggests that 30 percent of the work (and money) associated with the program should be retained in-house.
4. Insist that NASA keep the program as simple as possible. When complexity rises, so do overall costs—often exponentially. Complexity can arise from demands for international cooperation or the desire to spread work among many field centers. These demands are often irrelevant to mission objectives. Complexity can also result from the extensive use of formal systems management techniques. While these techniques are useful for promoting reliability, they are being supplanted in government and industry by leaner project teams whose members utilize less complicated forms of management. These management reforms, used on Project Pathfinder, the Near Earth Asteroid Rendezvous mission, and the Mars Exploration Rovers, allow project leaders to meet technically challenging mission goals while severely restraining mission cost.
5. Reward NASA officials when they make tough decisions. The restoration of focus and discipline will require difficult choices affecting existing installations and future programs. The recent history of human space flight suggests that agency officials may be reluctant to undertake needed change. Obstacles to change, moreover, may be more difficult to surmount than ones encountered in the past. The people managing Project Apollo built an organization from the ground up, expanding NASA's budget five-fold and its internal workforce by a factor of three. Proprietors of the current mission must work with an agency that will not be allowed to grow. If they sense that they are being punished for hard decisions, they may be reluctant to undertake needed change.

When planning for Project Apollo got underway in 1961, many of the participants had strong views about the mission. Some wanted to build orbiting space stations, and suggested that the expedition leave from a rendezvous point in low-Earth orbit. Others wanted to build enormous rockets, and recommended a strategy called direct ascent. Different centers wanted to be involved in different ways. An engineer from NASA's Langley Research Center tried to explain that America could not reach the moon by the end of the decade unless it utilized a spacecraft that remained in lunar orbit while two astronauts piloted another vehicle to the surface of the moon.

At first, the idea seemed preposterous. The United States had not conducted a successful rendezvous in Earth orbit, much less one around the Moon. More significantly, the idea upset the plans of people with different agendas. The engineer persisted. "Do we want to get to the Moon or not," he asked. The question silenced critics. The discipline of the mission forced people to forgo vested interests and work toward their common goal.

In a similar fashion, vested interests must fall if people in the space community seriously pursue this new goal. If they do, this new objective will be a transforming event, just as other great objectives were before it. If and when the United States completes the missions set out this year, the agency that does the work will bear little resemblance to the agency that exists today—just as the institution that landed humans on the Moon in 1969 hardly resembled the agency that received President John F. Kennedy's famous challenge in May, 1961.

Dr. Howard McCurdy is professor of public affairs and chair of the public administration department at American University in Washington, D.C. An expert on space policy, he recently authored *Faster, Better, Cheaper,* a critical analysis of cost-cutting initiatives in the U.S. space program. An earlier study of NASA's organizational culture, *Inside NASA,* won the 1994 Henry Adams prize for that year's best history on the Federal Government. He has also written *Space and the American Imagination* and co-edited *Spaceflight and the Myth of Presidential Leadership.* His work appears in scholarly journals such as *Public Administration Review* and *Space Policy.* He is often consulted by the media on public policy issues and has appeared on national news outlets such as the Jim Lehrer News Hour, National Public Radio, and NBC Nightly News. Professor McCurdy received his bachelor's and master's degree from the University of Washington and his doctorate from Cornell University.

Senator BROWNBACK. I hope it's not 20 or 30 years before we have people standing on Mars, that it's much sooner than that.

Thank you very much, Dr. McCurdy, for your testimony.

Mr. Tumlinson? Welcome back.

STATEMENT OF RICK N. TUMLINSON, FOUNDER, SPACE FRONTIER FOUNDATION

Mr. TUMLINSON. Thank you. Senator Brownback, Senator Hutchison, underappreciated staffers——

[Laughter.]

Mr. TUMLINSON.—I am really thrilled to be back here.

[Laughter.]

Mr. TUMLINSON. A few months ago, I sat in this room. I made one prediction, that sometime this year an American would fly in space, they wouldn't be a government employee, and they wouldn't do it on a government vehicle. I'm happy to say that the same day that America was looking backward at the Wright Brothers' demonstration, famed aircraft designer, Bert Rutan, broke the sound barrier with his prototype rocket vehicle. That prediction is on track, and I stick by it, at this point.

At the same time, I continued a call that we had been making for many years in the Space Frontier movement, that we return to the Moon, that we scuttle the Shuttle, that we move away from the Space Station, and that we set our sights on Mars, with the goals of permanent human settlement.

For many years, by the way, the Space Frontier Foundation has been holding Return to the Moon conferences. Our fifth will be this

summer. I wish the Senator from Nevada were here, because it's going to be in beautiful downtown Las Vegas, which, by the way, is a city that couldn't have been created by robots.

I want to agree with the last speaker, that, as currently constituted—by the way, I should say, strangely I was invited to the President's remarks. I sat about 20 feet away from him while he made the announcement, and I looked in my fellow Texan's eyes, and I studied him for the entire speech. I believe that he believes what he was saying. I believe that he was sincere about it. What I have difficulty with is how we will realize it. And I agree with the last speaker, that NASA, as currently constituted, cannot pull this off.

Forget the Moon, forget Mars, forget the space frontier out there. The greatest frontier facing NASA right now is itself. NASA is caught in a self-perpetuating loop of cultural traditions, inefficiencies, and systems that maximize waste and cost.

I want to give you an example. This is a carabiner. It's a little device that mountain climbers use around the world every day. They hang from them, they trust their lives to them. Astronauts also use these same devices to tether themselves to the Space Station. Now, you can go to REI or sporting goods shops and buy this device for about $20. NASA, on the other hand, pays roughly somewhere over a thousand dollars for this same object right now.

Now, why is that? It's not a case of some company ripping off NASA; it is a system of cost-plus rewards; it is a system of paperwork, rather than products; it is a not-invented-here mentality and a distrust of the private sector to provide such goods. The person who sells this to NASA has to create a stack of paper that takes weeks and weeks to fill out, that goes all the way back to the smelting and the origin of the metals that are put in this.

Now, the maximum load that is probably put on this device in space is around 50 pounds possibly, maximum a couple of hundred pounds. The REI version of this is rated at 6,500 pounds. This is the kind of thinking that has to change, or we will not be able to return to the Moon and go on to Mars for the budget or timescale that we're talking about.

We have to also move away from this distrust of the private sector that is out there, the mounds of paperwork that are required, the sorts of flaming hoops that the private sector is required to jump through, and the mindset that the private sector exists to serve as contractors for the government, rather than being a coequal partner in the opening of space.

If we are to return to the Moon and move on to Mars, and make it permanent, and not make it a flag and footsteps mission, it has to be an economically viable exercise. It can only be economically viable if profits and rewards are returned to our society. And those can only be realized by maximizing the creation of goods and services, and those are traditionally carried out in our society by the private sector.

We have to have an integral relationship with the private sector from day one; not only an exit strategy that says NASA is moving to the Moon to learn to go to Mars, and the moving out—which can be shown by, let's say, leasing facilities on the Moon, rather than building them and owning them—because, by the way, being on the

Moon, and operating a building on the Moon, and driving trucks to and from the Moon, will be as boring as it is driving to and from LEO eventually. NASA has to move on to Mars and keep going, where there are—and, by the way, Mars has a lot more exciting vistas than the Moon will provide. I'm not saying we're going to end up with a great civilization on the Moon. The civilization will occur on Mars and the worlds in between. Industry, the growth, the experimentation, the learning will occur on the Moon, and then we will move on.

I want to see NASA focus—by the way, one of the first places that we can get involved with the private sector is, shall we say, the entrance strategy, wherein the private sector is involved from day one in these plans, the private sector is involved in carrying astronauts from Earth to space. NASA's mission used to begin in the Earth and then go into space. No, NASA's mission now begins in space and goes to space. The idea that somehow the crew exploration vehicle is a new thing, as opposed to a magic wand waved over the orbital space plane, and turned it from a two-door into a station-wagon, is really the kind of thinking we're dealing with. They're going to go back and roll out the same projects they had before.

I want to see change. I want to see dramatic change occur. I want to see NASA do prizes, let's say, early data acquisition. If "prizes" is not a good word, let's call them contingency contracts. Put out $50 million for a photo map of the South Pole of the Moon, which is probably where we're going to put our facility, and offer a two-year time limit and see if a private company can do something in that time, and return those images. We'll save a lot of money, we'll mobilize a lot of private-sector activities, and we'll create a lot of excitement out there in the world, competitive excitement.

I want to see this all happen. And if we're going to inspire and create our excitement in our children, we have to quit going in circles; we have to go somewhere. We have to go fast, we have to go hard. We don't have to spend our time developing the absolutely highest tech, most expensive machine to get there. We've got to use what we've got. We've got to live off the land. Put the urgency and danger and joy of discovery together, and people will pay attention and support the program. Explore. Shine a light into a lava tube on the Moon. Dig for water in the Aitken Basin, and show us how to turn it into rocket propellent. Launch rockets off of the Moon. Go to Mars. Show the live camera shot from the helmet of the first woman to look into the Valles Marineris live on Earth. You want to see excitement that beats what we just saw with these robots? Let's do that.

And, for good measure, don't deny that people will die—given the anniversaries we're dealing with, that's a relevant point—or act surprised when it's going to happen. Let's make that risk a part of the message. Drop the obsessive lip service about safety, and let's actually do something about making things safe. Let's assure that NASA and our people in space are doing their best to be safe and adopting serious procedures to avoid death. But let's say, up front, that people will die on this quest. We know it's going to happen. Let's be aware of it and make it a part of it.

And once we're back on the Moon, let's not stop. It's just as boring, as I said, for NASA to be operating buildings there as it is to orbit the Earth round and round. Keep them going, moving ahead. The Lewis & Clark function, and I appreciate you saying that earlier. Let's send them over the hill, tell us what's there, but the settlers and shopkeepers move in after them and continue expanding the bubble of human life beyond the Earth. That is an exciting agenda, and that is an agenda that I think we can achieve and sustain.

Thank you.

[The prepared statement of Mr. Tumlinson follows:]

PREPARED STATEMENT OF RICK N. TUMLINSON, FOUNDER, THE SPACE FRONTIER FOUNDATION

Mr. Chairman, members of the Committee,

Just a few months ago I sat in this same room, calling for the United States to return to the Moon, as I and many in the space frontier movement have been doing for over twenty years. We in the Space Frontier Foundation have been calling for NASA to retire (or scuttle) the space shuttles, get out of Earth to LEO human and payload transport, and open the space station to commercial activities. We have also been calling for this Nation to redefine the relationship between the government and private sector space activities, so that a new partnership might be created which would lead to a vital and growing human frontier in space stretching from the Earth to the Moon and beyond.

A few weeks ago, I was privileged (and somewhat surprised, given my long history of criticism of our national space program) to be invited by the White House to attend the President's announcement that this Nation would indeed be returning to the Moon. As you can imagine I was pleased to hear that our message had been heard.

Ladies and gentlemen, I sat just a few feet from the President as he made his historic announcement, just as some of you did. And I looked into the man's eyes as deeply as I could during the whole speech. I believe he means what he is saying. I believe he truly wants us to begin opening space to the American people, to establish this Nation permanently on the Moon and from their to catapult ourselves to the planet Mars and beyond.

I am not so naïve as to be unaware of the political aspects of his announcement, dropped into the middle of the primary season of the opposing party, nor the positive note it adds to his own candidacy for re-election. But I am also aware of the downside of making such an announcement in a campaign year, especially at time when many who oppose his policies will be automatically pre-disposed to attack the ideas he spoke of, simply because they came from his mouth. Just as if, were he to say the sky is blue, his opponents would immediately argue that it is not. So to be honest, there is both an up and a down side to his timing. In fact, a part of me wishes he would have waited until after the elections, as I do not wish to see the Democratic party make a knee jerk reaction that rejects the core concepts of his proposal.

The fact that this plan is designed to begin with small incremental down payments that grow like the balloon payment on a home mortgage in the years after he leaves office also does not go unnoticed. But I can attribute this to the desire to make the idea a bit easier to swallow now, and is based on his confidence that our national economy will be able to handle such costs when the bill comes due. Even with major growth in our national space budget, the numbers spoken of are much smaller than the relative cost of our first push to the Moon was to our over all GDP.

I think the timeline is too slow—after all we went to the Moon from an almost standing start, developing three or four new launchers (if you count the LEM) and did it all in 7 years over 35 years ago. Let's get some challenge in there! It will help to focus and drive our space program. Also, I believe International partnering should not be based on State Dept. motives, but who can do the best work in a given area at the best price. International deals are done every second in the private sector on just such a basis.

Finally, the real private sector MUST be involved early on, not as a show, not as an after thought. If the Moon base is to turn into a settlement or community,

it has to be designed to do so from day one. For example, as I discuss below, after the scouting and base camp phase, it would be good to see something along the line of NASA offering to rent X square feet of the buildings for X number of years or some such scheme that builds in the idea that NASA is not trying to yet again take on more facilities and overhead, but is just passing through on the way to Mars.

However, overall, I am supportive of the concept as outlined in his speech.

The Moon, Mars and the asteroids that float between the worlds of our solar system do indeed represent the future of humanity. It would be pure ignorant hubris to declare that we should not expand our species and the domain of life beyond this Earth, much like the declarations of a serf in medievil Europe proclaiming that the world ends just beyond the boundaries of his own village. Similarly, there is the short term thinking that leads to the conclusion that somehow science and the advancement of knowledge will somehow be damaged by the growth of human activities in space. As if the exploration and settlement of this new world where we sit today somehow held back the march of scientific progress, rather than driving our advancements and understanding of ourselves and the universe forward at a pace unknown before our ancestors struck out into the unknown. We are truly just at the bare beginnings of the story of humanity and the life forms of the Earth. And we stand poised to take bold steps outwards—if we can do so wisely, economically, and for the right reasons. Those reasons are as wide and varied as those who look at the Moon and stars at night and feel their calling. Many speakers have laid out the possibilities, from Dr. Paul Spudis, who sang of the possibilities offered by the Moon, to Dr. Rober Zubrin, who waxes poetic about the vast vistas available to us on the planet Mars, Dr Gerard O'Neill, my mentor, who created a vision of humanity spreading out in colonies of glass and steel in the space between worlds.

All of these visions can be made real. All of the benefits to us these men have spoken of *are* real, as are a thousand more they could no more imagine than those who first came to this new world could imagine that the land they were exploring for gold and glory would give the world the Bill of Rights, the Constitution, and an ongoing revolution in thought, science and medicine that has completely transformed our human civilization.

And therein lies the big question. Does the President's proposal leads to the Real opening of the frontier—by which I mean the expansion of the human domain beyond the Earth? Not outposts, not stations, not laboratories, but economically viable and growing communities of human beings that can eventually become new branches of our civilization. For if that is not the end point of this exercise, then, as some in our science community have said repeatedly, we should send robots instead. Also, if this endeavor is to be led by and for the government, and the above is its litmus test for success, it will fail. Government's do not open frontiers. People do—with the assistance of their governments, and sometimes in spite of those same governments.

To succeed Every possible way to produce value (Include scientific value as well as economic) must be combined. If those two elements are then put into an equation, and the end result is positive or can be projected to turn positive we have a winner. If not, we have a negative cash/value flow and a loser. (NOTE—None of these elements was considered or kept on the table for ISS!)

—Put giant KISS! (Keep It Simple Stupid!) posters everywhere, in all centers and offices. Give rewards for designs and ideas that go that way instead of the high tech, over specialized direction. For example, Rutan trumpets the fact that his flyers are the lowest technology, most off the shelf he could build, and where possible, units and structures are duplicated (look at the shapes etc. of his carrier and sub-orbital elements—cast in the same molds). Learn the lesson and apply it to the Moon. If a Home Depot bolt will work, use it. If you can go with voltages, air pressures etc. that make things simpler, then do it. Save high tech for later . . .

—Rather than designing the habs etc. themselves, NASA should stay Lewis and Clark—like and focus on such things as scouting expeditions, and an early base camp that is designed to be expandable. Then put out a call to the non-space community for facilities that are low cost, robust, low maintenance and modular or expandable on a larger scale. NASA and other agencies could then sign ten or fifteen year leases, indicating (in the case of NASA) they are not planning on squatting down on the Moon but are moving on. (not ISS redux on the Moon.)

—So some NASA guy will look out there and say "we can't find any firms engaged in the right kinds of activities or willing to partner with us." Duh. Talk about self-fulfilling prophecy. Of course not. You killed them all over the last thirty years, or trashed their ideas and killed off their investors, or supported your aerospace friends to the point you drove them out of business.

The private sector has been so burned for so long by NASA in the past that they must be coaxed back into space. Sponsor events and meetings with people in the

military, business and commercial research/transport/life support communities and listen to them. Oil platforms, private diving bells and Navy subs, Hilton Hotels, airlines, all have lessons that can be transferred to this effort. The private sector has done a fair job of turning this New World into a permanent and expanding frontier. I bet they can help a little on the next one.

The International Space Station

As we move forward to the Moon, the International Space Station should be transformed into a multi-faceted nexus for both government and private sector activities. Some of these activities will be in support of the Lunar effort, and some will not, but all will contribute to the development of a vibrant human presence in LEO.

In his speech the President said:

> "Our first goal is to complete the International Space Station by 2010. . .finish what we have started."

Let me make a few important points:

—Almost all the original goals laid out for the space station have already been abandoned. It needs to be redefined and the program totally reformed or this will not happen.

—We are not in charge of the station. We have partners who are using it for their own purposes, and interestingly, many of those partners are moving quickly towards private sector dominance of their activities and areas on station—as should we.

—As the agency is cutting back its level of participation, there will be other orbital facilities, including the first space hotel modules, if entrepreneurs such as the self-funded Bob Bigelow in Nevada are to be believed (and given his wealth, determination and the realistic basis of his plans as revealed so far I do believe him.) other firms are looking at modules that might attach at first to the ISS and then through a "budding" process become independent free flying facilities themselves. Remember, the Chinese will also be flying their own facility by that time. This all means that a community can be developed that will create an economics of scale, a mutual interdependence and back up capability in case of disasters and accidents. (See my 1995 Testimony to the House Space Subcommittee on the idea of "Alpha Town" the first community in orbit.)

I used to be in favor of what I called an International Space Station Authority. This would have been a mechanism to wrest control from NASA and hand it to a more commercial friendly entity that would be less likely to play favorites when it came to which companies would provide services, establish the rule of law, set safety standards etc.

As a great military strategist once said that the commander who cannot change his tactics based on changes on the field of battle is doomed to lose. Thus I have dropped the ISSA concept, since NASA is planning to divest its majority ownership one way or the other in the coming years.

The future I see for the facility would be one wherein NASA's role would become that of a tenant, who's main focus is the preparation and experimentation it needs to plan missions to Mars. I would like to see the U.S. Government set up a management structure for the U.S. portion that would allocate NASA what it needs, and also open the rest of our ISS elements up to private sector use. This could mean anything from university operated labs and experiments to commercial research. Also, the new charter would allow and encourage the attachment of new modules, probably completely commercially owned and operated that could house experiments, and even accommodations for commercial guests such as future Dennis Titos (who I had the honor of signing up to fly into space a few years ago). Another commercial activity would be a construction shack and factory operated by commercial astronauts based on Dennis Wingo's on orbit assembly concepts. These space workers would be engaged in activities such as on-orbit construction of large space telescopes, antenna arrays, large space probes and even the ships to travel to Mars.

One major idea would be to have the Hubble space telescope moved by an orbital tug to an orbit above the ISS, so that it could be lowered to the facility for astronaut EVAs to service it. The Hubble is far too valuable a resource to throw away, and NASA plans to do so are expensive, limited in vision and reveal a complete lack of understanding of the frontier ethic of keeping things low cost by re-using and recycling whenever possible.

Space Transportation

The President said:

> "Our second goal . . . to develop and test a new spacecraft, the Crew Exploration Vehicle, by 2008, and to conduct the first manned mission no later than 2014 . . ."

—I can see the SEV becoming the new OSP/X–33/NASP/X–38/etc.—a cash draining, show killing tech project. NO NO NO! if every element in the transportation part of the equation isn't low cost, robust and re-usable or designed to become so ASAP, then let's quit now and go home as this project is DOA.

—By the time NASA speaks of pulling out of its major role on ISS, there will probably be other players in the Earth to LEO transportation arena, so the support of ISS will not be a limited sum game. There may well be a wide array of possible Earth to Leo transportation alternatives. The private sector firms that make up what I call the Alternative or Alt.Space transportation firms will be well on their way to becoming full fledged orbital access providers—if the government can provide the regulatory and investment incentives they so desperately need if they are incentivised to cross from largely being sub-orbital or small payload orbital companies into the orbital game by prizes and multiple source pay for delivery services.

—NASA must get out of the Earth to LEO business entirely. An astronaut's mission used to start on the Earth's surface. This will no longer be true. They will be able to ride into space on private vehicles, and NASA can save its time and funds working on the next leap—between planets. I know some think there will be an all-in-one vehicle developed for transit from Earth surface to these other worlds, but such a concept is ridiculous, short sighted and probably the most expensive way such movement can be accomplished. If one reads the President's policy carefully, and from a frontier perspective, the call for a crew Exploration Vehicle can be read as meaning a transporter that lives in space, and goes to and from destinations there, without returning to Earth itself. (A model that makes far more sense than carrying all of the hardware one would need for transits in and out of our atmosphere.)

—The Near Frontier transportation system will need a re-fueling capability that can circumvent the incredibly high costs of bringing propellant up from the Earth's surface, and a port for flights to and from the Moon and eventually Mars. Paul Spudis and others have advocated mining Lunar elements at the poles of the Moon and using them to create "space gas" that can then be shipped down the gravity well and used to re-fuel all kinds of space craft, and satellites. I understand one might not wish to have a space "gas station" in close proximity to inhabited facilities, but it can be developed and constructed using ISS astronauts. The NASA institutional side of the facility could contract out services from the commercial team if needed for fueling their Mars ships.

—I am also concerned that projects like the planned nuclear Prometheus vehicle and other high tech space-to-space elements will pace and slow down the program. This must not be allowed to happen. Stay simple at first. Get the first rope across the ravine, then work up to the foot bridge and then go for the super highway. Start development early though, so your needs intersect with your capabilities down the road. . .so to speak.

As I discussed last fall, there is a growing alternative space movement there in America. Whatever NASA does or does not do, this community, which is investing tens of millions to develop new space vehicles and orbital facilities, will open the space frontier in its own way. While America turned its eye to the past at Kittyhawk this December, famed aircraft designer Burt Rutan's sub-orbital rocket ship broke the sound barrier in Mojave, California. Few noticed, and fewer understand what this means. But as I also noted in my previous testimony, the goal of flying the first non-government rocketship into space is on track to be realized before the end of this year. Elon Musk's SpaceX will be flying small payloads into orbit at a dramatically lower cost per pound than current government vendors within the same time frame, and at least a half dozen other firms are on track to cross the finish lines in this alternative space race.

I mention this to let you know that there really are potential commercial partners out there beyond the current NASA contractors. The door to space is about to be blown wide open.

The Moon

The President said:

> "Our third goal is to return to the Moon by 2020."

Most of the comments I would make on this third element of his plan are contained in the following OpEd.

Return to the Moon—For the Right Reasons, in the Right Way *(from an editorial in Space News)*

> "We do this and the other things not because they are easy, but because they are hard . . ."

President John F. Kennedy—from his speech announcing Apollo.

Any discussion of a permanent return to the Moon (RTM) must be centered on two over riding questions: "Why?" and "How?" The answers to each of those questions are interrelated and one affects the other. If we go for the wrong reasons we will fail. If we go for the right reasons and do it the wrong way, we will fail. And if we don't go at all, then we will have failed in a way that will send ripples down through the ages.

There are many different answers to "Why?" They include: far side observatories to seek life on other worlds; studies of Earth's history by studying the Moon's surface and geology; near side Earth observation telescopes (Triana on the Moon); searching for platinum class metals in asteroids buried in the surface; giant solar arrays beaming power to communications satellites and solar sail transports; isolated laboratories to try new and dangerous schemes; taking the high ground militarily; driving the creation of new technologies; and of course, backing up the biosphere and human civilization in case of catastrophe and expanding the domain of life and humanity.

There are also a few more subtle reasons we go:

We go to force the re-structuring of our national space activities.—NASA's human spaceflight program today is like an old ex-athlete who won the Olympics a long time ago. It is bloated, inflexible, self-indulgent, and lives on re-runs of its better days. It is neither inspiring nor useful. In fact, it is harmful, as without a mandate to move out to the Far Frontier of the Moon and beyond, NASA has squatted down in LEO and claimed it as its own, blocking any who might try to do anything useful on its "turf." We can let it slowly die, or we can trim the fat and get it into shape by making it get out of the doorway to space, back into the arena, and forcing it to run again—this time with a team-mate called private enterprise—to whom it can hand the baton at the right moment.

We go to inspire.—The most important thing we got out of Apollo was inspiration. It was a star of hope in the darkness of the Cold War. It was the reason I am in this field, and the same goes for many of you reading this. The internet, telecom, the incredible advances in medicine and science, these breakthroughs are coming from organizations whose founders and investors were often born and raised during the Apollo program, and while its legacy was still fresh. If one looks at the numbers of engineers and science students graduated in the U.S., there is a clear correlation, and right now those numbers are falling, fast.

We go to prepare for even greater things.—We cannot throw expendable humans at Mars without knowing what happens to a spacesuit in a high radiation, high temperature differential, dirty, vacuum after its been worn and sweated in for six weeks. We need to learn how to operate off planet, how to build for permanence and how to live off the land in space. Also, those who advocate a direct drive to Mars ignore a major historical fact—the colonies in North America could not have survived without the ports of England and Europe. The development of a strong Earth-LEO-Moon infrastructure, dominated by commercial enterprises, is a necessity, if humans-to Mars is not to be another unsustainable flags and foot prints fiasco or perennial taxpayer funded government housing project.

The "How?" of returning to the Moon partially determines the "Why?" For example, if the timeline is too long, the budget too large, the end goal too amorphous, and the whole project is run by the usual suspects in the usual way, the end result will be an uninspiring, over budget dead end like the International Space Station (ISS). To make a Return to the Moon permanent, inspiring, economical and beneficial to the taxpayers who pay for it all, we must do the right things.

The Greatest Frontier

All of these ideas, for a new and revitalized ISS, for a return to the Moon, the establishment of the first space settlements, and the dream of expanding life beyond Earth, will not be achievable if we do the wrong things, proceed in the wrong manner, and aim at the wrong goals.

First, we must ignore the whining of those who say they need a lot more money and time. We went from a standing start to standing on the Moon in under ten years—forty years ago! Keep in mind, when Kennedy asked the NASA of that time

if it could be done, they told him no, and then they went and did it when ordered to.

Next, we must restructure NASA, as the agency in its current form cannot handle the job. The center-based structure of today must be ended and several non-relevant centers closed or handed over to other agencies. Activities such as aeronautics and Earth studies must be handed off to the FAA and NOAA. Planetary robotic exploration should be given to JPL and the National Science Foundation (NSF).

NASA must shed operational activities such as LEO transport and running the space station. The Orbital Space Plane should be canceled—now. Prizes, multiple source contracts, investment and tax incentives must be put in place to encourage the new Alt.Space firms to take over human transport to space, and drive the traditional aerospace giants to modernize or get out of the field. The space station should be mothballed, handed to our partners or be taken over by a quasi-commercial Space Station Authority as a destination for commercial and university users. ISS and other NASA pet projects must not be grafted onto a moon project simply because they exist. If they really support it they are in, if not, they are out.

What is left should be divided into two parts. The first should be a lean mean human exploration machine that focuses on the Lewis and Clark function and acquiring or creating the lowest tech tools possible to travel and explore beyond the Earth. The second should be an agency like the old National Advisory Committee for Aeronautics from which NASA was created. Its job would be to push the envelope of space technologies and systems in support of our space industries.

The new NASA would then be one of several players in any RTM project along with DOD, DARPA, NOAA, NSF, universities, and most importantly, the commercial sector. NASA will support planetary transportation systems development, scouting, surveying and pitching the first base camp, then others take over as the agency focuses on developing systems for Mars exploration—it's next destination.

For the Moon Base to survive and prosper, it must be built in the right spot, it must be robust, easy to operate at low cost, as self sufficient as possible and be easy to expand. The International Space Station is failing because it is in the wrong place, too delicate, too expensive to operate, and produces nothing of great value—scientific or commercial. To pay for the Moon Base we must combine a wide variety of income producing activities and services, such as those listed above. BUT, the people building the habitats after the first phase, operating the telescopes, and running the facility itself should NOT be government employees. The long term Lunar facilities should be designed and built by private firms in response to a short list of needs put out by the partners, with the U.S. government leasing those it needs. Long term management of the base should be in the form of a Moon Base Authority to promote new activities, manage infrastructure, oversee safety, and enforce the law.

Tied to the Earth with Red Tape

Forget the Moon, forget Mars. The greatest frontier NASA has to face is itself. From timid bureaucracies to over burdening regulations and procurement rules to outright "Not Invented Here" turf oriented jealousies, NASA'S culture must be changed, and this mandate must come from outside of the agency, and even from beyond the scope of the new commission being formed as we speak to look into how to accomplish these goals. Without dramatic, near—term and permanent changes the President's initiative will fail. And I am very afraid that the discussion now underway is nowhere near strong enough nor has it reached deeply enough to force logical people to make the hard choices needed.

For example, at a level above the agency, we must modify the overly burdensome Federal Acquisition Regulations or throw them out completely in favor of fee for service and delivery business style operations. Along the way the incredible piles of paperwork NASA uses to certify and manage each piece of hardware should be pared to a minimum. The space community is rife with examples of NASA loading potential providers down with paperwork. Sometimes even the simplest sounding deal is drowned in paper. Safety and quality needs to be assured certainly, but at some point it gets ridiculous.

This story came to me from Bill Haynes, a former Air Force test pilot.

"(Consider) the carabiners astronauts use to tether themselves during EVA. The best climber's carabiner at REI costs $19.00.

I found the manufacturer of NASA's carabiners, and he said he charges $1,095.00 each. When I told him about REI's, he said sure, he could probably sell his for a $100 or so, except that NASA requires a "pedigree" all the way from the mine for every ounce of aluminum in his, his welders and machinists each have to be re-certified every six months and the paperwork stack that accompanies each carabiner is inches high.

That might make sense for say, the turbine buckets in the Space Shuttle Main Engines. It makes absolutely no sense for those carabiners that will never encounter more than about a fifty lb. load in space.

The REI carabiners are rated at 6,500 lbs."

This approach to the business of space will not get us to the Moon again.

New Approaches

Every possible way to produce value (Include scientific value as well as economic) must be combined and every way to reduce costs must be found. If those two elements are then put into an equation, and the end result is positive or can be projected to turn positive we have a winner. If not, we have a negative cash/value flow and a loser. (NOTE—None of these elements was considered or kept on the table for ISS!)

—Put giant KISS! (Keep It Simple Stupid!) posters everywhere, in all centers and offices. Give rewards for designs and ideas that go that way instead of the high tech, over specialized direction. For example, Rutan trumpets the fact that his flyers are the lowest technology, most off the shelf he could build, and where possible, units and structures are duplicated (look at the shapes etc. of his carrier and sub-orbital elements—cast in the same molds). Learn the lesson and apply it to the Moon. If a Home Depot bolt will work, use it. If you can go with voltages, air pressures etc. that make things simpler, then do it. Save high tech for later . . .

—Rather than designing the habs etc. themselves, NASA should stay Lewis and Clark—like and focus on such things as scouting expeditions, and an early base camp that is designed to be expandable. Then put out a call to the non-space community for facilities that are low cost, robust, low maintenance and modular or expandable on a larger scale. NASA and other agencies could then sign ten or fifteen year leases, indicating (in the case of NASA) they are not planning on squatting down on the Moon but are moving on. (not ISS redux on the Moon.)

—NASA should offer to buy data wherever possible. Prizes should be offered for milestons that can be reasonably offered to the private sector. Or if the word "prizes" is unpalatable, let's call them "contingency contracts". For example, within the next year or so a short term, let's say 2 year "contingency contract" of around $80 million could be offered for high resolution images of the potentail base camp site at the Lunar south pole. If it is won, we get our information scheap and spur several new firms into action. If not, there is still plenty of time for NASA to launch its own probes.

—So some NASA guy will look out there and say "we can't find any firms engaged in the right kinds of activities or willing to partner with us." Talk about self-fulfilling prophecy. Of course not. NASA killed them all over the last thirty years, or trashed their ideas and killed off their investors, or supported thier aerospace friends to the point you drove them out of business.

The private sector has been so burned for so long by NASA in the past that they must be coaxed back into space. Sponsor events and meetings with people in the military, business and commercial research/transport/life support communities and listen to them. Oil platforms, private diving bells and Navy subs, Hilton Hotels, airlines, all have lessons that can be transferred to this effort. The private sector has done a fair job of turning this New World into a permanent and expanding frontier. I bet they can help a little on the next one.

I was heartened to see the inclusion of language in the President's policy that indicated an awareness of these needed changes, but I m still concerned that bureaucratic inertia will swallow any new and radically different ideas (or what those of us outside of the agency might call "common sense").

The idea of an outside commission to lay the groundwork for this push outwards is a good idea. But it needs to be vested with real authority, and be comprised of space experts, business leaders and "out of the box" thinkers. Unfortunately I am concerned the deck is already being stacked the wrong way, even if it is not being done so consciously.

The leadership of the commission for example, must be free of all ties to those who stand to benefit from its deliberations, nor should they have that appearance. This is not to question the integrity of anyone who might volunteer their time to do this important work, but to avoid any questions whatsoever about the validity of their findings and plans. I am hopeful that such considerations are going into the selection process, and any such issues are being rectified.

If the right people are assembled for this work, and given the mandate that appears in the president's speech—namely to open the space frontier, then I am confident thatlogic, history and common sense will prevail in their plans. I hope the White House, this body and NASA in particular pay attention, interact with them

and move on their recommendations. I would also hope that the commission be empaneled to revisit this new space agenda on a regular basis.

Conclusion

In conclusion, I think we have before us an exciting and powerful vision. We need not empty the coffers of our Nation to make it happen, and in fact will create enourmous new wealth, in the form of both economic and scientific wealth. If we can employ the power and genius of free enterprise we can transform our moribound space program into something incredible. But the people in this room, in this building and in this town must lead this time, and not be led, by lobbiests and Center Directors, party bickering and pork barrel politics. Let's get back to exploring. Let's let loose our reborn Lewis and Clarks to blaze the way for new generations and let's make sure everyone, especially those at NASA know they are spending our money to clear the way so we can follow. The space program will then get all the support it needs.

For if we want to inspire and create excitement in our children We must go somewhere! Go fast, go hard, and don't wait around developing the absolutely highest tech most expensive machine to get there. Use what you've got and go! Live off the land. Put the urgency of danger and joy of discovery together and people will pay attention. Explore! Shine alight into a new lava tube on the moon . . . Dig for that water in the Aikin basin, show the blast off of the first mission to Mars, launched from the Moon . . . the pale blue marble of Earth in the distance. Feed that helmet camera shot of the Valles Marinaris to the world. And cover it live, good or bad, success or failure, life or death . . .

For good measure, don't deny that people will die, or act surprised when it happens—make that risk part of the message . . . drop the obsessive lip service about safety and focus on being safe . . . assure that NASA and our people in space are doing their best to be safe, adopt serious procedures to do avoid death . . . but say up front that people will die on this quest.

And once we are back to the Moon DONT STOP . . . it will be just as boring for NASA to be landlord on the Moon as in LEO. Show some learning. Get there, scout, set up the beginnings of the base. As others move in (universities, institutes, commercial users) the agency can go off in a nearby crater and begin developing its planetary surface exploration capabilities, then move on to Mars, where the vistas are larger and the opportunities for long term excitement abound. But don't squat down again. MOVE.

Senator BROWNBACK. Thank you, Mr. Tumlinson. Appreciate the panel very much.

A couple of questions, then I'll turn to my colleague from Texas.

Dr. Friedman, are we in another space race now? You cite several other countries with planned missions to Moon. Do you believe we're in another space race, that we can be left behind if we don't engage these sort of activities and strategies that you've outlined?

Dr. FRIEDMAN. Sometimes, when I'm glib, the only space race I describe is the humans-versus-robots space race, that I think we're both evolving—I mean, this in a serious way—that we're both evolving technologically, and it's—probably the main reason I support human spaceflight is because I think it's part of our human evolution to go to other worlds.

I don't think we're in a space race with other countries. I think the ability—the need for the United States to prove itself, technologically, as a dominant space player is not necessary, as it was in the 1960s, when we undertook Project Apollo. If anything, the challenge before us is to learn to cooperate with other countries and to work with the great buildup that's going on in Europe, which is now conducting two planetary—which has now conducted two planetary missions successfully, and has a long-range plan also for the Moon and Mars; Japan, which is doing two missions to the Moon and has talked about building a robotic infrastructure on the Moon; and China, who is obviously an emerging space power; and other

countries, as has been cited, are developing rocket capability to go to space.

The challenge is, is to work with these countries. It's a—it will help us immeasurable, as it has in so many commercial industries to be working internationally.

Senator BROWNBACK. Dr. Friedman, if I could, because my time's going to be very limited here. What you described to me is a space race that—whether we choose to enter it or not is probably the question. I mean, we need to cooperate, clearly, with other countries, but if we don't engage a new vision for NASA—if we say it's too risky, it's too costly—other people, other countries are going to the Moon and beyond, is that correct?

Dr. FRIEDMAN. I accept that. That's correct, Senator. Yes, I think that's—it's a very good point—that the space race is not the one of competitiveness of trying to prove our greatness, but the space race is the one that's inherent in our civilization to try and prove ourselves.

Senator BROWNBACK. Whether we enter it at all, or whether——

Dr. FRIEDMAN. Correct.

Senator BROWNBACK.—we decide that's just too risky or too expensive, we're not going to go there. Others are.

Dr. FRIEDMAN. I think that the reasons for going there are more than just that others are; it's really about what we say about ourselves, as well.

Senator BROWNBACK. Well, I agree with that.

Dr. LANE AND DR. McCurdy, you both talked about reorganizing, or a transformational experience at NASA. I guess really all three of the other panelists. What are the biggest impediments that Congress can be positively involved in in this transformational experience that NASA will need to be—need to happen? Where should we focus our light or our energies to see that this NASA transformation takes place?

Dr. LANE. Well, Mr. Chairman, my experience has been that previous Administrators have made the significant attempts to realign NASA, reorganize NASA, reallocate the funds to make the whole better than it is, remove some of the waste that my colleague just referred to a few minutes ago. But when you make those changes, and talk about reallocation, it implies a change of money and people; jobs, then, are at stake. And with centers all over the country immediately coming to the defense of their employees and their position in the state, understandably, phone calls get made. And certainly——

Senator BROWNBACK. So you're saying we're really going to have to pull NASA in, focus it on fewer areas, and we're going to have to get the extraneous spending under control?

Dr. LANE. My view is that it will require focus, and focus is going to be more than parsing out a complicated plan to the same units, same people, in the same locations.

And I would also add that each time Congress earmarks NASA's budget, it is not necessarily a bad project, I'm not suggesting, but it's not necessarily a priority project for NASA. It removes some of the flexibility that the Administrator has to reallocate funds, to reorganize.

So there are several things Congress can do, but what I said in my testimony was, the White House and Congress really needs to get behind the Administrator. When you're satisfied with the Administrator's plan, get behind the Administrator and prevent these end runs that will undo the best intentions, which I'm sure he has.

Senator BROWNBACK. Dr. McCurdy, anything on this?

Dr. MCCURDY. Focus on cost. When Jim Webb, the NASA Administrator, came before this Committee in 1961, he predicted that we could go to the Moon for about $20 billion. The cost of Project Apollo through Apollo 11 was $21 billion. Focus on cost. Focus on total program cost. Don't let this policy become a Lourdes for NASA, a place where the field centers and existing programs go to get well. That's what I'd suggest.

Senator BROWNBACK. Mr. Tumlinson, I want your thought on an offer of a $50 million reward—kind of like what we did in Iraq in getting Saddam Hussein, but this timer to engage the private sector with a reward for whoever can get a post set up, I guess, on the south pole of the Moon. And you think that we could by dangling a certain amount of an accomplishment fee out there get and engage sufficient private sector capital to get these things accomplished?

Mr. TUMLINSON. Yes. And the examples are out there. My organizations funds—offered a prize at one point for small rocketry. We had a lot of people respond.

I'm founding trustee of a thing called the X Prize that has stirred rocket competition around the world, one of the rockets—Burt Rutan's vehicle—which is being funded, by the way, by Paul Allen, of Microsoft. They're going to spend about $35 million to win a $10 million prize.

So the idea of prizes—and, again, if we—you know, we can go into NASA-speak, or whatever—contingency contracts, they do inspire innovation. There's a long history of that, all the way back to the British Navy, working on a better timekeeper for its ships, put out a prize, a very famous book written about that.

So these things do work. I'm not talking about putting a base up for $50 million, by the way. I'm talking about returning high-resolution photographs, something—the idea of orbiting satellites or probes or that type of thing is—the private sector has shown that. They launch communications satellites all the time. There are companies that have that kind of an interest, and that's a number that might inspire them. People smarter than I can probably work out the exact, sort of, relevant price for that. But I think it will inspire people and get people—you know, there's nothing like a race. Americans love a race and a competition, and I think that's a way to get people involved and lower costs.

Senator BROWNBACK. Well, my view of this is that we need to tap into the private sector capacities, abilities, and capital to be able to——

Mr. TUMLINSON. Absolutely.

Senator BROWNBACK.—do some of the things that we want to do. And it's not enough to just be able to compete for resources at the public sector, which is going to have a lot of different pushes and political interests.

But if you can tap into that, and if there's a way of being able to do that, I hope you or a group of other people that are thinking about this will get to Pete Aldridge's Commission to put in some very specific sort of thoughts about what portions of these missions could be done by the private sector if there's a contingency contract or something of that nature. We would see what sort of capital we could tap into and what we can put off to the side on our budget, while we focus on something that can't be, right now, done through the private sector. I hope you'll put forward specific ideas on that.

Mr. TUMLINSON. Yes, a couple of points I'd like to make there is, we have to end this antagonistic relationship between NASA and the private sector.

While I'm at it, I'm going to plug a friend's book, called *Lost in Space: The Fall of NASA, and the Dream of a New Space Age,* by Greg Klerkx. Please read this book. It talks about how these situations have come up in the past, how that antagonism has grown, and where we are right now with the alternative space movement, versus the space agency, and where we could possibly go in the future.

For example, on the Moon, why not have Hilton provide the housing? You know, why not have the food provided by commercial food providers. Or, it may not be politically PC to talk about, but the services being provided to the troops in Iraq on their bases are being provided, basically, commercially. You know, a cheeseburger is a cheeseburger; it doesn't have to be designed by NASA scientists. So I think we could work at those kind of situations. But NASA has to learn that the private sector can be a partner, and learn how to work with them and not talk down to them, not try and dominate.

NASA should focus on science, should focus on exploration. There will be no private companies that are going go try to do landers on Mars. That's an appropriate role for the space agency. But these other types of activities, space transportation, in particular, from Earth to LEO, running the Space Station, et cetera, let the private sector step in. It's time.

Dr. MCCURDY. Senator, look to Antarctica as a model of private-public cooperation.

Senator BROWNBACK. That's a good thought.

Senator Hutchison?

Senator HUTCHISON. Well, thank you very much. I appreciate having the second panel, because I think you all have been refreshing and very candid; and, in many instances, what you've said will lead us to do some other things.

I would like to ask Dr. Lane a couple of questions. Of course, I do know Dr. Lane, and appreciate so much the role that he has taken advising me on scientific projects and things that we can do to highlight better. And I was pleased, in your testimony, that you mentioned the National Space Biomedical Research Institute, that it's headed by Baylor College of Medicine, in Houston, Texas, and that's a good repository for the information that's coming down through NASA and the Johnson Space Center. But it has about 15 other medical schools and universities all over the country, and I think it is a way that we can do something that you suggested as the fourth goal, and that is to assure that we continue to try to be

in the forefront, as a country, in science and engineering, and also to assure that we encourage young people to come into science.

My question is, What more do you think we should be doing to achieve that fourth goal as we are now going to refocus on space exploration? What can we do, both in assuring that we keep the engineering and science component—which I did ask the Administrator if he was going to maintain the ongoing commitment there, and he said yes—but also, what should we be doing to bring younger people into the excitement of the engineering and research jobs and careers that we want them to pursue?

Dr. LANE. Thank you, Senator. I think the most important thing that Congress can do is to look carefully at the plan when it comes out initially in the President's budget, and then in continued interactions with NASA, to see, in fact, if what I've suggested should be a fourth goal really is, because I, with respect, did not hear that in the Administrator's comments and his presentation. I did hear a number of enterprises emphasized in connection with the President's announcement. I did not hear science being placed up quite so high on that list.

The reason I think it's so important, and particularly the university support, is because that's really where many of the young people are making their final decisions, if you like, or a final decision in their educational process what their career is going to be. That's where students who think they're going to be scientists and engineers have second thoughts and do something else.

If there's something exciting that attracts them, if they have an opportunity to engage in research that's as exciting as what we've seen here today, that can capture a young mind. That's precisely the kind of thing that can build a cohort of young scientists and engineers, in our states and in our nation, to work on projects like space exploration. But they'll be attracted by those few years in the university when they have a chance to get a taste of research.

So I think NASA's research programs, at the university level, are particularly important. And to the extent that you can look at those and look at the way those are cooperative with agencies like the National Science Foundation and other agencies so that you build a much larger impact that each agency on its own, I think there's a chance to do much more, even with the same amount of money.

So I urge you, please look carefully at what the plan is that gets rolled out, and then stay with it along the way to see whether science is more important than I think I heard in the Administrator's comments this morning.

Senator HUTCHISON. Did you hear—I want to hear from you, but let me ask you this—is there a large amount of interaction and cooperation between the National Science Foundation and its projects, and NASA?

Dr. LANE. I think there certainly is good cooperation. I don't know how to scale it. I don't have numbers in mind. But, as you know, Senator, NSF takes responsibility for most of the ground-based observation, the telescopes that are mounted right here on solid Earth; and NASA, for the space-based telescopes. But both agencies support an enormous amount of research in universities by theoretical and experimental astronomers and astrophysicists,

and I know the agencies interact so that each agency understands, in detail, the program of the other agency.

I'm not worried about wasteful duplication, somehow, of support of effort; I'm more interested in coordination, to make sure things don't fall through a crack.

Senator HUTCHISON. Well, just to pursue that, I was just wondering if there were a function that NSF could provide from the NASA part of that space research, since they do so much in university research grants and programs. Could they take that as a function, not to duplicate what NASA's doing, but to maybe take that responsibility for that goal and make, you know, their mandate perhaps even more relevant than, in some instances, maybe it is?

Dr. LANE. I think it would be very useful for both agencies to clarify, for the science community, their respective roles in—and the work they do together—in astronomy, astrophysics, space-related research, because I think in just doing that, both agencies will see some opportunities for supporting the university activity that perhaps not being supported right now.

Both agencies have a long history of supporting university research. So NASA put together some of the first——

Senator HUTCHISON. But NSF is a different type. It's more peer-review based, grant-request based, which is different, I think, from NASA, which is why I——

Dr. LANE. Both agencies use peer review. They do use it somewhat differently, and I think—along with other science agencies—it would be useful to—everybody could improve their system of peer review, and I do—I'm a believer in peer review. I think, with all of its blemishes, it is the best way to assure that the best science and engineering research gets supported.

But different agencies do it differently, and I think there's an opportunity for all of them to learn from one another and to improve the way all agencies are supporting science. So I would definitely encourage those kinds of discussions and perhaps hearings on the subject.

Senator HUTCHISON. Dr. Friedman, did you have something to add?

Dr. FRIEDMAN. I was just going to add, your question about motivating young people, that we should get that video that we saw this morning out. That's a tremendous motivation. We have a lot of experience with that. And NASA, to their credit, on this very mission, has an educational experiment with a DVD and a sundial up there, that were produced for other technical purposes, but they—we've been engaging students with it in a very cooperative, privately funded educational activity with NASA.

Senator HUTCHISON. Any others to add to that?

Dr. MCCURDY. Well, my generation was raised on Buck Rogers, *Collier's* magazines, and Tomorrowland at Disney World. The new generation is interested in space to the same degree, but for different reasons. And I think the Administration has tapped into that with the mixing of robotic and human capabilities. Kids are really interested in robots, electronics, virtual reality. And so, to the extent that that mix continues in the program, I think it will attract the young generation to want to be scientists and engineers

and support it—support the space program in the same way that us, here, in our generation, are supporting it now.

Senator HUTCHISON. Yes, Mr. Tumlinson?

Mr. TUMLINSON. Yes, two quick points on that issue. One is, I agree with everything that's been said, and the idea that you could grow up, and actually be somebody exploring Mars yourself someday is very exciting.

Regarding the NSF/NASA relationship, to me one of the exciting things about the Moon is that it doesn't have to be an all-NASA project. And I'm not just talking about the commercial sector. Why not have NSS—NSF-grant winning universities operating far side observatories, as opposed to NASA, those types of things, and bring in, shall we say, more slices of the government pie there to supplement the kind of budgets they have?

Senator HUTCHISON. Well, let me just add one more thought. Recently, I was listening to Dr. Malcolm Gillis, who is the head of your institution, Dr. Lane, he remarked that when Dr. Richard Smalley and his partner were—it was announced that they were awarded the Nobel prize for nanotechnology research, they were teaching freshman chemistry. And I thought, in addition to what you have said, to have our stars in the field, the astronauts or other scientific stars, to reach out and teach freshman or high school students would also be very exciting. I can't even imagine what a freshman would think when, the day that they are taking their freshman chemistry class, their professor is awarded the Nobel prize.

Dr. LANE. I think they'd think, "Is my homework still going to be due at the end of the period?"

[Laughter.]

Senator HUTCHISON. You're probably right. Just to take away all the magic.

Mr. TUMLINSON. Senator Hutchison, real quick, you mentioned nanotechnology. We've talked a lot about the inspiration for education. There's a great picture of the late Dr. Gerard O'Neil, who was a major space advocate, working with a mass driver device that he was working on that was going to be used to deliver payloads off the Moon. In the picture, is one of his young proteges working with him. The kid's name was Dr. Eric Drexler. He created the nano movement and the name and the entire concept. He was inspired by space. I just wanted to bring up that little note.

Senator HUTCHISON. Well, it's very important.

And I would say, to Dr. Lane, in addition to homework, I do think that probably those young people are making up the scientists of the future because they are so inspired.

Well, we do have a vote on, and that's why Senator Brownback has left, but thank you very much. This was very helpful and, I think, will be part of our oversight of NASA as we move into a very exciting era.

Thank you. We are adjourned.

[Whereupon, at 12:10 p.m., the hearing was adjourned.]

A P P E N D I X

PREPARED STATEMENT OF HON. HARRISON H. SCHMITT, CHAIRMAN, INTERLUNE-INTERMARS INITIATIVE, INC.

TWO PATHS TO THE MOON

Harrison H. Schmitt[i]

Summary

Left unstated in the President's challenge to NASA and the Congress is an implicit challenge to the private sector of the United States to join in our re-invigorated migration into deep space. That sector of American life, particularly the entrepreneurial and investment risk-takers among us, should move forward in parallel with NASA's new efforts, protecting this unique foundation of American freedom. If private enterprise is to participate as more than useful and necessary contractors to NASA, then systematic business initiatives must be launched that will equal or exceed the technological and financial pace of publicly funded space efforts.

In the tradition of public-private parallelism, private space-related initiatives not only can benefit from the research and technology development funded by NASA, but they can supplement, support, and, if necessary, pick up the baton of space settlement if not carried forward by government. The financial, environmental, and national security carrot at the end of a long stick is access to low cost lunar helium-3 fusion power.

A private, lunar resource-oriented enterprise will take a different technical path back to the Moon than that taken by NASA. This dichotomy of approaches will be best for all concerned. More conceptional options will be explored, more engineering approaches examined, and more opportunities for beneficial outcomes created. For example, to provide competitive returns on investment in its lunar endeavors, the private sector will want heavier payload capability and lower cost in Earth to the Moon launch systems than will NASA. Further, its spacecraft will be specialized for the tasks of landing reliably and precisely at known resource-rich locations on the Moon rather than serving two or more masters.

A private lunar initiative will not and should not be immune to appropriate regulatory oversight by cognizant agencies of government. Similarly, such and initiative must follow existing space law, as established by U.S. statute and the Outer Space Treaty of 1967 to which the U.S. is a party. Specifically, in the case of the Outer Space Treaty, the private sector and the U.S. Government have a mutual interest in interpretations that encourage both explorers and entrepreneurs.

The entrepreneurial private sector has an obligation to support a return to the Moon to stay, as now articulated by President Bush. We also have an obligation to follow our own path to get there in order to be additive to the overall goals of settling the Solar System and improving lives for those who remain on Earth. Once humans permanently inhabit the Moon, only the migration of human families out of Africa 150,000 years ago and of other families successfully seeking freedom in the New World 550 years ago will have had comparable survival and philosophical impact.

FULL TESTIMONY

President George W. Bush has challenged NASA to once again "explore space and extend a human presence across our solar system." Those who believe in the future and in freedom embrace this vision of permanence in space for Americans and for humankind. His new initiative places the President squarely in support of the movement of civilization into the solar system and "into the cosmos." If sustained by Con-

[i] Harrison H. Schmitt landed on the Moon on Apollo 17, served in the U.S. Senate, and is currently Adjunct Professor of Engineering at Wisconsin-Madison and Chairman of Interlune-Intermars Initiative, Inc.

gress and future President's, American leadership of this expansion of the ecological reach of our species will be accompanied by the transfer of human freedom, first to the Moon, then to Mars, and, ultimately, beyond.

Left unstated in the President's challenge to NASA and the Congress is an implicit challenge to the private sector of the United States to join in our re-invigorated migration into deep space. That sector of American life, particularly the entrepreneurial and investment risk-takers among us, should move forward in parallel with NASA's new efforts, protecting this unique foundation of American freedom. If private enterprise is to participate as more than useful and necessary contractors to NASA, then systematic business initiatives must be launched that will equal or exceed the technological and financial pace of publicly funded space efforts.

America has a tradition of parallel commercial and public technological initiatives, ranging from transportation to agriculture to communication to medicine. The development of private trading routes, turnpikes, canals, and railroads joined with the Army's Corps of Discovery, military expeditions and the Corps of Topographical Engineers, and the Corps of Engineers to open the American frontier. Scientific research and technological innovations arising from the Land Grant College and University system have supported American farmers and associated agricultural businesses. Commercial aircraft and ground transportation industries grew in concert, respectively, with the research activities of the National Advisory Committee on Aeronautics and the construction of the Interstate Highway system. Satellite communications, the first venture into space related business by private investors, was catalyzed by NASA's pioneering experiments and demonstrations in the late 1950s and throughout the 1960s. The explosion in the quality of health care and in longevity since the 1930s has come in association with research breakthroughs by both the private sector and the National Institutes of Health. Many other beneficial and synergistic examples of parallelism between private and public institutions can be cited. The combined efforts of such institutions clearly have been far more productive then either would have been acting alone.

In that tradition of public-private parallelism, private space-related initiatives not only can benefit from the research and technology development funded by NASA, but they can supplement, support, and, if necessary, pick up the baton of space settlement if not carried forward by government. The financial, environmental, and national security carrot at the end of a long stick is access to low cost lunar helium-3 fusion power. As we reach toward the Moon and its resources, the development of fusion technologies will open new business opportunities in medical diagnostics and treatment, weapons detection, nuclear waste elimination, and clean electrical power generation. Longer term, ancillary businesses will be possible because of low cost access to space resulting from the demands of lunar resource acquisition. These additional business opportunities include providing services to the government related to lunar and planetary exploration and science, national defense, and long term, on-call protection from asteroids and comets. Space and lunar tourism also will be enabled by the existence of such capabilities in the private sector.

A private, lunar resource-oriented enterprise will take a different technical path back to the Moon than that taken by NASA, although cooperative research and technology development projects would be helpful to both. This dichotomy of approaches will be best for all concerned. More conceptional options will be explored, more engineering approaches examined, and more opportunities for beneficial outcomes created. Indeed, successful commercial applications of fusion and space technologies to human needs and desires will underpin the private enterprise approach in contrast to the policy driven foundation of NASA's approach.

To provide competitive returns on investment in its lunar endeavors, the private sector will want heavier payload capability and lower cost in Earth to the Moon launch systems than will NASA. Its spacecraft will be specialized for the tasks of landing reliably and precisely at known resource rich locations on the Moon rather than serving two or more masters, such as, the International Space Station and a Lunar Base. The private initiative will concentrate on lunar surface vehicles and work facilities that provide reliable, low cost resource recovery in addition to general mobility and habitat. It also will require highly mobile and low maintenance space suits that are at least half the weight and four times the mobility of Apollo suits and that have the glove dexterity of the human hand. All vehicles, facilities, and space suits will be designed for indefinite operational life rather than mission life, including embedded diagnostics, anticipatory component replacement, and ease of maintenance and refurbishment. Any required automated precursor missions to gather additional resource development information will use low cost, data specific approaches rather than attempt to meet broad, higher cost scientific objectives.

Management structures for a private initiative will follow proven corporate approaches and the best business practices of comparable, high technology enterprises.

These structures would be modified, as appropriate, by the many lessons learned from Apollo relative to work in the complex and unforgiving environment of deep space. The Board of Directors and senior management will deal with programmatic issues involving planning, investors, conceptual approach, financial control, marketing and sales, governmental interfaces, public affairs, and the spin-off of ancillary businesses. Under this protective umbrella, responsibility to meet technical objectives will be delegated to centers of excellence. A system of independent technical oversight will exist to assess the centers' readiness to proceed past designated programmatic milestones.

To minimize the amount of required inter-center coordination (and competition), centers will specialize, respectively, in Earth launch systems, spacecraft and flight operations, lunar resource extraction and processing, lunar surface support facilities, and fusion power systems. Centers of excellence will have internal design teams working in parallel with the implementing contractors, providing managers with two sources of information and opinion related to design and configuration control issues. Quality control and assurance will be managed as an internal responsibility of all employees and not a centralized function of corporate headquarters. Critically, personnel management for the corporation will be charged with the need to maintain center organizations peopled largely by workers in their 20s and managers in their 30s.

From early in its history, operational control of lunar surface operations will be placed on the lunar surface. Resource marketing and sales will be managed at corporate headquarters on Earth until such time as that function can reasonably be transferred to the Moon as well. To minimize cost and capitalize on experience for its lunar surface operations, a private initiative will hire and support employees who wish to be settlers. With the first landing, the initiative's intent will be that employees stay on the Moon permanently. All support functions, including medical treatment and rest and recuperation, will be provided on the Moon, not by a trip back to Earth. A clear constraint on the design and operation of launch vehicles and spacecraft will be that there can be no Space Shuttle-like stand-downs in the case of accidents. Rather, confidence in all hardware must be such that the next planned launch can proceed essentially on schedule.

A private lunar initiative will not and should not be immune to appropriate regulatory oversight by cognizant agencies of government. Similarly, such and initiative must follow existing space law, as established by U.S. statute and the Outer Space Treaty of 1967 to which the U.S. is a party. Specifically, in the case of the Outer Space Treaty, the private sector and the U.S. Government have a mutual interest in interpretations that encourage both explorers and entrepreneurs. As with research and technology development of critical enabling engineering approaches, it would be highly beneficial to have a private-federal partnership in articulating an enabling legal environment for deep space. An example of enabling legal cooperation would be an extension of private property rights from near-earth space to the Moon, Mars, Asteroids, and deep space in general, without a claim of national sovereignty as prohibited by the Outer Space Treaty.

The entrepreneurial private sector has an obligation to support a return to the Moon to stay, as now articulated by President Bush. We also have an obligation to follow our own path to get there in order to be additive to the overall goals of settling the Solar System and improving lives for those who remain on Earth. Once humans permanently inhabit the Moon, only the migration of human families out of Africa 150,000 years ago and of other families successfully seeking freedom in the New World 550 years ago will have had comparable survival and philosophical impact.

Mars Society Statement on Bush Space Initiative

January 24, 2004

On January 23, 2004, the following statement concerning the new Bush space policy was ratified by the Steering Committee of the Mars Society. The vote was 19 in favor, 3 abstentions, none opposed, and 5 not voting.

Bush Speech Opens Door

The Future is Up to Us

Statement of the Steering Committee of the Mars Society
January 23, 2004

On January 14, President George Bush gave a speech at NASA headquarters outlining a new strategic orientation for the American space agency. While some of the initial ideas for implementing the new space policy can and should be substantially improved upon, the policy overall clearly represents a significant and long-overdue step in the right direction for the American space program. The Steering Committee of the Mars Society therefore welcomes the new policy as presented in Presidential Directive entitled "A Renewed Spirit of Discovery," and strongly urges Congress to provide the funds requested for the initial steps requested for the program over the next Fiscal Year.

Our analysis of the important strengths and required areas for improvement of the new policy is presented below.

Analysis

As stated, the new Bush space policy offers both opportunities and pitfalls to those interested in furthering human exploration and expansion into space in general, and Mars in particular. While not representing the start of an actual Moon/Mars program, since nearly all serious spending for hardware systems other than the crew capsule is deferred to administrations coming into office in 2009 or beyond, it does in fact clear the ground for the initiation of such a program should the 2009 administration be so inclined. It also provides a certain amount of free energy that, if handled properly in the 2004–2008 period, could be used to help insure the emergence of a powerful human exploration initiative within the time frame of the 2009 administration.

In his speech, Bush redefined the purpose of the American space program as the "establishment of a human presence throughout the solar system." This statement may seem to some like a mere rhetorical flourish, but it actually has important concrete programmatic significance, as it legitimizes NASA spending supporting technology development for human exploration of the Moon and Mars. Such spending was forbidden under the previous order of things, and for the past ten years technologists seeking funding for important human Moon/Mars exploration technologies had to justify them by arguing their value for other established programs, such as the JPL-led robotic exploration program or the ISS. This has made it impossible to obtain adequate funding for many technologies, such as planetary in-situ resource utilization (ISRU), and has led to disasters such as the promising JSC-led Transhab inflatable habitation program, which was derailed when the discovery that planetary exploration technology work was being done under ISS cover led to cancellation by congressional staff. It is for this reason that the Mars Society has had since its Founding Convention in 1998 campaigned for the establishment of a NASA line item for the support of human exploration technology development, so that such activity could take place openly. Bush's initiative fully accomplishes this objective, with healthy initial program funding. For this reason, if no other, Bush's move must be seen as an extremely positive development.

The new policy will also create a program organization at NASA headquarters, called Code T, which will significantly raise the level of NASA efforts to develop efficient plans for human planetary exploration. This is also a welcome development.

In addition, the Bush policy also provides a basis for including human exploration research requirements within the design of robotic planetary missions. In the late nineties, representatives of the human exploration missions office at JSC attempted to utilize flight opportunities aboard the JPL-led robotic Mars exploration landers, but as the JSC researchers had neither a mandate nor money, they had neither force nor funds to back up their requests, and were dealt with accordingly. Under the new space policy, both a mandate and funds should be available to support human exploration related research and technology flight experiments aboard robotic lunar and planetary spacecraft. This could allow such payloads to either fly as paying customers aboard the JPL/Code S sponsored science spacecraft, or alternatively, support the funding of human exploration program controlled robotic

landers whose primary mission would be to provide engineering data for the human exploration program, with other science payloads carried on a space available basis.

The Bush policy also identifies where the funds required to support a true human exploration initiative will come from, to wit the redirection of the existing Space Shuttle and ISS budgets. Currently, the Shuttle budget runs about $4 billion per year, while the ISS budget is between one and two billion. This total of $5–$6 billion per year is more than sufficient to get humans to both the Moon and Mars within ten years of actual program start. Thus the initiative can be done within the existing NASA budget of about $16 billion per year in 2004 dollars, a level found supportable by presidents and congressional majorities of both political parties for the past four presidential terms. Thus the financial basis for the program is clear, and is not a budget buster or in any way fantastical.

In his speech, the President invited all nations to join with the United States in pursuing the proposed program. We welcome this statement, as we fully agree that the exploration and settlement of the solar system is a great goal that can help bring humanity together, one that is worthy of, and requires, the mobilization of the best talents of all the peoples of the Earth.

For various political and diplomatic reasons, the Bush policy delays the phase out of the Shuttle and ISS until2010, thereby delaying substantial human exploration program start until about that time. Thus the choice on whether or not to really start a Moon or Mars human exploration program, and what its pace or objectives should be, is effectively being placed in the hands of the 2009 administration.

The merit of this decision is debatable. A key point however, is that the 2009 administration will have a choice. By making clear that the fundamental purpose of the human spaceflight program is to allow humans to FLY ACROSS SPACE (the Apollo era vision) to explore other worlds, rather than to allow humans to EXPERIENCE SPACE (the Shuttle era vision), the Bush policy (should it be sustained by either his reelection or the concurrence on this issue of an alternative 2005 administration) effectively precludes the commitment ofNASA to a second generation Shuttle ("Shuttle 2") as its next major program. As recently as a few months ago, substantial factions within space policy circles in both congress and NASA projected such a Shuttle 2 program as the agency's next major project after ISS. Had that occurred the future would have looked like this: the present decade would be consumed with returning the Shuttle to flight and building ISS. The next decade would be devoted to extending the life of Shuttle and developing Shuttle 2. The 2020s would then be a repeat of the 1980s, attempting to make Shuttle 2 operational, leading to a decision in 2030 on the next major project, which probably would have been ISS–2. Thankfully, this "Groundhog Day" scenario for perpetual stagnation in space has now been foreclosed on.

The decision to punt the responsibility for implementation, and thus the control, of the program to the 2009 administration promises to make the next five years an extremely interesting time for space advocates. In his speech, Mr. Bush defined human expansion into the solar system as NASA's goal, and posed the idea of a lunar base initiated by 2020 as the strategy by which this objective might be approached. That is one plan, but the next five years will see other plans put forward for consideration by the political class as efficient means by which the desired overall goal can be achieved with maximum speed, reliability, and at minimum cost. The great debate on what our strategy for reaching the Moon and the planets should be has thus not been closed by Bush's speech, but opened.

The victory in this healthy battle of ideas will go to those people who convince the players, not merely of today, but of2009 and beyond, of the merit of their concepts. The Mars Society welcomes this challenge, and will seek to actively participate in this discussion to contribute its technical expertise and to convey an understanding to the political class, the technical community, the press, and the public that within the context of the new space policy, that the near-term human exploration ofMars is feasible, affordable, and truly worthy of the efforts and risks required.

In transitioning from one kind of space program to another, every effort should be made to prevent unnecessary collateral damage to valuable parts of the old program. The decision announced by NASA headquarters late last week to abandon the planned Shuttle mission to upgrade and reboost the Hubble Space Telescope (HST) is an example of the kind of mistake that needs to be avoided. The Cosmic Origins Spectrograph and Widefield Camera 3 designed to bring the HST to its full potential have already been built and tested, and promise an enormous scientific return upon delivery to orbit. If the Bush plan were to stand down the Shuttle immediately, and save the $24 billion required to operate it through 2010 so as to initiate the Moon/Mars program with substantial funding immediately, that would be one thing. But given the decision to return the Shuttle to flight, canceling the Hubble upgrade

would only save about $200 million, or 1 percent of the Shuttle program's budget, while destroying about 90 percent of its scientific value. This is extremely foolish.

Safety arguments won't wash either; if the Shuttle is safe enough to fly to the ISS, its safe enough to perform its mission to Hubble. Indeed, while Shuttle missions to the Hubble may lack the on-orbit safe-haven of the ISS, the low-inclination of Hubble flights enables launch aborts to warm tropical waters, where crew survival chances are much better than in the frigid north Atlantic abort sites required by ISS launches. Moreover, it is difficult to understand how an agency which is too risk adverse to undertake a Shuttle mission to Hubble could possibly be serious in considering a mission to the Moon or Mars.

The cancellation ofthe Hubble mission can thus only be described as a serious mistake, apparently committed in the name of the desire to appear "decisive" in breaking from the old paradigm in favor of the new. In addition to the harm done to astronomy, it would be a very bad thing for the infant new space policy to begin its life with a such a distasteful record. Under no circumstances should the alleged impending availability of the James Webb Space Telescope be accepted as a rationale for abandoning Hubble, either. That would be to repeat the mistake NASA made in abandoning the Saturn V for the supposedly superior Shuttle, or Skylab for the ISSerrors which set back the space program by decades of time of tens of billions of dollars. IfNASA's leadership will not see reason on this issue, Congress should take forceful action to reverse this very bad decision.

Technological Issues

The right way to do a program whose objectives encompass both a permanent lunar base and the human exploration ofMars is to design a set of transportation hardware that can accomplish human Mars missions, a modified modular subset of which can be used to support lunar activities. Approaching the problem in this way can save a great deal of time and money, as only one hardware set needs to be developed instead of two. It also maximizes the value of the Moon as a testing ground for Mars, since under this approach to Moon missions will be done using the Mars hardware, and serve directly to shake it out. Provided this is the approach adopted, a program initiated in 2009 could easily achieve piloted lunar landing by 2015 and launch the first human Mars expedition by 2018. The build up of a permanent lunar base and continued Mars missions could then occur simultaneously. Since it is only possible to launch to Mars every other year in any case, the implications of a running concurrent programs are simply that the lunar program launch rate would be reduced somewhat during Mars launch years. Concurrent launch programs would also serve to minimize launch costs by maximizing the rate of production of the booster production lines, as the cost of running a launch vehicle manufacturing facility increases only marginally with a higher production rate. To use a mundane analogy, it takes very little extra labor to cook two steaks instead of one, provided you cook them both at the same time. In the production of launch vehicles this kitchen parable holds even more force, as labor costs overwhelmingly dominate those of materials.

Within the context of such a well-planned Moon/Mars program, there are certain technologies that are essential. We address only two of the most critical, heavy lift boosters and ISRU.

Heavy Lift Boosters

The key technical instrumentality required to make lunar bases and Mars missions feasible is a heavy lift vehicle with a hydrogen/oxygen upper stage capable of throwing payloads in the 50-tonne class on Trans-lunar or Trans-Mars injection. This is the capability demonstrated during the 1960s by the Saturn V. Once such a vehicle is available, roundtrip Lunar missions or one-way delivery of habitations and other heavy payloads to the lunar surface can be readily accomplished with a single launch. Piloted Mars missions can also be accomplished using multiple discrete Trans-Mars launches of such a system, with no on-orbit assembly, as shown by the Mars Direct plan (Zubrin and Baker, 1990), the Stanford Mission plan (Lusignan, et al 1992), or the JSC Design Reference Mission 3 (Weaver et al, 1994).

Such Saturn V class launch systems can be readily created at this point either by converting the Shuttle launch stack through elimination of the orbiter and its replacement with a LO_x/H_2 upper stage, or the creation of new, all-liquid propulsion booster systems. The Mars Society was recently shown plans by one major aerospace company for evolving its existing line of medium lift boosters to create a family of modular heavy lift boosters with payloads ranging through quarter, half, and full Saturn V capabilities. Based on this company's experience with previous successful launch vehicle developments, the entire development program to create the whole family of boosters could be accomplished in five years with a development cost of

about $4 billion. The recurring launch cost for the Saturn V class system design was $300 million per launch, or less than $1000/lb for payload delivery to LEO. The methods of creating such booster families are obvious to experienced launch vehicle engineers, and we have no doubt that this company's competitors have plans for creating similar hardware sets with comparable development costs and schedules.

The claims by certain pundits opposed to any exploration initiative that a new heavy lift booster would cost tens of billions to develop can thus readily be shown to have no basis in fact. Such heavy lift vehicles would also have many applications outside of the human exploration program.

ISRU

Both lunar bases and Mars expeditions are strongly benefited through the use of in-situ resource utilization (ISRU) techniques for the production of return propellant, human consumables, and vehicle fuels and oxygen for use in extended missions on a planetary surface. The mission mass savings for either lunar bases or Mars missions resulting from ISRU has been demonstrated in numerous studies, and significantly exceeds that offered by advanced propulsion concepts with much higher development and recurring system costs.

Effective ISRU require both chemical processing systems and reliable sources of power, for which space nuclear systems offer the greatest promise. We therefore strongly commend the administration for its Prometheus project to create such space nuclear systems. However we note that up until now, the sole applications considered by NASA for its space nuclear power systems have been spacecraft power and nuclear electric propulsion (NEP). Without dismissing the important value ofNEP for outer solar system robotic missions and other missions involving large velocity changes undertaken across extended time frames, we note that the size ofNEP units required to supply propulsion for human exploration missions are on the order of 10,000 kilowatts. In contrast, when used to produce chemical propellants on planetary surfaces, the required reactor size to support human exploration is reduced to about 100 kilowatts. This is because a much smaller reactor stationed on a planetary surface making propellant can emit energy over a long period of time prior to flight, store it as chemical propellant, which then can release the energy as fast as it is needed under flight conditions. The mission mass leverages achieved by such ISRU supported chemical propulsion options are greater than those offered by NEP, while for inner solar system missions, the flight times are less (two orders of magnitude less for Lunar applications). In addition, the ISRU-supported chemical systems can be used not only for orbital transfer, but for planetary ascent.

Thus while space nuclear power is enabling for ISRU, it is ISRU that greatly reduces the cost, and increases the value of space nuclear power in supporting human exploration. The two technologies should thus be pursued in parallel, and an appropriate fraction of the Prometheus budget applied towards bringing ISRU applications of space nuclear power to flight status, and to support robotic missions demonstrating such technology on the Moon and Mars.

Furthermore, requirements should be written into the Prometheus program to insure that the power systems developed are compatible for operation on the surface of the Moon and Mars, since their use on the planetary surface to produce propellants and consumables represents by far the most advantageous method of employing them to support near-term human space exploration, and their power is needed on the surface to support base operations in any case.

Both ISRU technology and heavy lift booster development should thus be central priorities of the Code T effort over the immediate period.

Other systems should be developed with similar concern for maximum commonality of hardware and technology across lunar and Mars mission applications.

Political Implications

The train of events set in motion by the new space policy will create a decision point circa 2009 that will offer three alternatives for future action. These are;

(a) The 2009 administration could choose to abort the Moon/Mars program altogether, and simply use the Crew Exploration Vehicle (CEV) as a capsule launched atop expendables as a way of continuing to visit the ISS. This would lead to a Mir-type extended ISS program, conducted at lower cost than possible using Shuttle launches, but with no discernable purpose. This would result in stagnation in space for however long such a programmatic decision prevailed, and probable retrogression on heavy lift, ISRU, and other programs necessary for human exploration.

(b) The 2009 administration could decide to proceed in accordance with idea of building a lunar base, starting 2020, without concern for the Mars mission except to make claims that lunar experience will no doubt be useful later when

others contemplate going to Mars. This would result in the development of mostly incompatible lunar program hardware (except the booster), making it necessary to start developing an entire new hardware set circa 2030, or possibly 2040, given the budgetary entanglements such a stand-alone lunar program would create, making it likely that the first Mars landing would not occur before the middle of the 21st Century. Alternatively, given the limited interest provided by repeated dead-end Lunar expeditions, the program could simply expire.

(c) The 2009 administration could decide to launch a humans to Mars program, with the objective of reaching Mars within ten years, with expeditions to the Moon using a modified subset of the Mars flight hardware beginning around program year 7. Because only one hardware set would need to be developed instead of two, and because in aerospace cost equals people times time, this represents a much lower cost approach to achieving the goals set forth in the new space policy than alternative (b). Moreover, it is the only approach that will result in human explorers walking on Mars within the working lifetime of any adult today.

It is therefore imperative that everyone who wishes to see the human exploration of Mars become a reality do everything he or she can to fight for the bold course represented by option C. In the labs and engineering organizations, in the press, in the classroom and the committee room, in the Arctic and in the desert, in the halls of congress, and in every venue of public opinion ranging from books and technical papers to Internet newsgroups and late night talk radio, each will need to play their part.

A door has been opened, and a battle of ideas that will determine the shape of the human future for many years to come has now been truly joined. Where it will lead is up to us. Contending visions that two weeks ago were mere hypothetical debates among space activists have now entered the center of political discourse. We welcome the challenge. For as reason is our witness and courage is our guide, we shall prevail.

A Renewed Spirit of Discovery

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

PRESIDENT GEORGE W. BUSH

JANUARY 2004

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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.

A Renewed Spirit of Discovery

Today's Presidential Action

- Today, President Bush announced a new vision for the Nation's space exploration program. The President committed the United States to a long-term human and robotic program to explore the solar system, starting with a return to the Moon that will ultimately enable future exploration of Mars and other destinations.

- The President's vision affirms our Nation's commitment to manned space exploration. It gives NASA a new focus and clear objectives. It will be affordable and sustainable while maintaining the highest levels of safety.

- The benefits of space technology are far-reaching and affect the lives of every American. Space exploration has yielded advances in communications, weather forecasting, electronics, and countless other fields. For example, image processing technologies used in lifesaving CAT Scanners and MRIs trace their origins to technologies engineered for use in space.

Background on Today's Presidential Action

America's history is built on a desire to open new frontiers and to seek new discoveries. Exploration, like investments in other Federal science and technology activities, is an investment in our future. President Bush is committed to a long-term space exploration program benefiting not only scientific research, but also the lives of all Americans. The exploration vision also has the potential to drive innovation, development, and advancement in the aerospace and other high-technology industries. The President's vision for exploration will not require large budget increases in the near term. Instead, it will bring about a sustained focus over time and a reorientation of NASA's programs.

- NASA spends, and will continue to spend, less than 1 percent of the Federal budget. Our Nation's investment in space is reasonable for a tremendously promising program of discovery and exploration that historically has resulted in concrete benefits as well as inspiring Americans and people throughout the world.

- **President Bush's Vision for U.S. Space Exploration**

  The President's plan for steady human and robotic space exploration is based on the following goals:

  - ✓ First, America will complete its work on the International Space Station by 2010, fulfilling our commitment to our 15 partner countries. The United States will launch a re-focused research effort on board the International Space Station to better understand and overcome the effects of human space flight on astronaut health, increasing the safety of future space missions.

    - To accomplish this goal, NASA will return the Space Shuttle to flight consistent with safety concerns and the recommendations of the Columbia Accident Investigation Board. The Shuttle's chief purpose over the next several years will be to help finish assembly of the Station, and the Shuttle will be retired by the end of this decade after nearly 30 years of service.

  - ✓ Second, the United States will begin developing a new manned exploration vehicle to explore beyond our orbit to other worlds – the first of its kind since the Apollo Command Module. The new spacecraft, the Crew Exploration Vehicle, will be developed and tested by 2008 and will conduct its first manned mission no later than 2014. The Crew Exploration Vehicle will also be capable of transporting astronauts and scientists to the International Space Station after the Shuttle is retired.

For more information on the President's initiatives, please visit www.whitehouse.gov

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- ✓ Third, America will return to the Moon as early as 2015 and no later than 2020 and use it as a stepping stone for more ambitious missions. A series of robotic missions to the Moon, similar to the Spirit Rover that is sending remarkable images back to Earth from Mars, will explore the lunar surface beginning no later than 2008 to research and prepare for future human exploration. Using the Crew Exploration Vehicle, humans will conduct extended lunar missions as early as 2015, with the goal of living and working there for increasingly extended periods.
  - ➢ The extended human presence on the Moon will enable astronauts to develop new technologies and harness the Moon's abundant resources to allow manned exploration of more challenging environments. An extended human presence on the Moon could reduce the costs of further exploration, since lunar-based spacecraft could escape the Moon's lower gravity using less energy at less cost than Earth-based vehicles. The experience and knowledge gained on the Moon will serve as a foundation for human missions beyond the Moon, beginning with Mars.
  - ➢ NASA will increase the use of robotic exploration to maximize our understanding of the solar system and pave the way for more ambitious manned missions. Probes, landers, and similar unmanned vehicles will serve as trailblazers and send vast amounts of knowledge back to scientists on Earth.

➢ Key Points on the President's FY 2005 Budget

- ✓ The funding added for exploration will total $12 billion over the next five years. Most of this added funding for new exploration will come from reallocation of $11 billion that is currently within the five-year total NASA budget of $86 billion.
- ✓ In the Fiscal Year (FY) 2005 budget, the President will request an additional $1 billion to NASA's existing five-year plan, or an average of $200 million per year.
- ✓ From 1992 to 2000, NASA's budget decreased by a total of 5 percent. Since the year 2000, NASA's budget has increased by approximately 3 percent per year.
- ✓ From the current 2004 level of $15.4 billion, the President's proposal will increase NASA's budget by an average of 5 percent per year over the next three years, and at approximately 1 percent or less per year for the two years after those.

➢ President's Commission on the Implementation of U.S. Space Exploration Policy

To ensure that NASA maintains a sense of focus and direction toward accomplishing this new mission, the President has directed NASA Administrator Sean O'Keefe to review all current space flight and exploration and direct them toward the President's goals. The President also formed a Commission on the Implementation of U.S. Space Exploration Policy to advise NASA on the long-term implementation of the President's vision.

➢ Space Technology Affects the Lives of Every American

More than 1,300 NASA and other U.S. space technologies have contributed to U.S. industry, improving our quality of life and helping save lives.

- ✓ Image processing used in CAT Scanners and MRI technology in hospitals worldwide came from technology developed to computer-enhanced pictures of the Moon for the Apollo programs.
- ✓ Kidney dialysis machines were developed as a result of a NASA-developed chemical process, and insulin pumps were based on technology used on the Mars Viking spacecraft.

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- ✓ Programmable Heart Pacemakers were first developed in the 1970s using NASA satellite electrical systems.
- ✓ Fetal heart monitors were developed from technology originally used to measure airflow over aircraft wings.
- ✓ Surgical probes used to treat brain tumors in children resulted from special lighting technology developed for plant growth experiments on Space Shuttle missions.
- ✓ Infrared hand-held cameras used to observe blazing plumes from the Shuttle have helped firefighters point out hot spots in brush fires.
- ✓ Satellite communications allow news organizations to provide live, on-the-spot broadcasting from anywhere in the world; families and businesses to stay in touch using cellphone networks; and the simple pleasures of satellite TV and radio, and the convenience of ATMs across the country and around the world.

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1-14-04

the White House
President George W. Bush

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For Immediate Release
Office of the Press Secretary
January 14, 2004

Remarks by the President on U.S. Space Policy
Nasa Headquarters
Washington, D.C.

3:25 P.M. EST

THE PRESIDENT: Thanks for the warm welcome. I'm honored to be with the men and women of NASA. I thank those of you who have come in person. I welcome those who are listening by video. This agency, and the dedicated professionals who serve it, have always reflected the finest values of our country -- daring, discipline, ingenuity, and unity in the pursuit of great goals.

America is proud of our space program. The risk takers and visionaries of this agency have expanded human knowledge, have revolutionized our understanding of the universe, and produced technological advances that have benefited all of humanity.

Inspired by all that has come before, and guided by clear objectives, today we set a new course for America's space program. We will give NASA a new focus and vision for future exploration. We will build new ships to carry man forward into the universe, to gain a new foothold on the moon, and to prepare for new journeys to worlds beyond our own.

I am comfortable in delegating these new goals to NASA, under the leadership of Sean O'Keefe. He's doing an excellent job. (Applause.) I appreciate Commander Mike Foale's introduction -- I'm sorry I couldn't shake his hand. (Laughter.) Perhaps, Commissioner, you'll bring him by -- Administrator, you'll bring him by the Oval Office when he returns, so I can thank him in person.

I also know he is in space with his colleague, Alexander Kaleri, who happens to be a Russian cosmonaut. I appreciate the joint efforts of the Russians with our country to explore. I want to thank the astronauts who are with us, the courageous spacial entrepreneurs who set such a wonderful example for the young of our country. (Applause.)

And we've got some veterans with us today. I appreciate the astronauts of yesterday who are with us, as well, who inspired the astronauts of today to serve our country. I appreciate so very much the members of Congress being here. Tom DeLay is here, leading a House delegation. Senator Nelson is here from the Senate. I am honored that you all have come. I appreciate you're interested in the subject -- (laughter) -- it is a subject that's important to this administration, it's a subject that's mighty important to the country and to the world.

Two centuries ago, Meriwether Lewis and William Clark left St. Louis to explore the new lands acquired in the Louisiana Purchase. They made that journey in the spirit of discovery, to learn the potential of vast new territory, and to chart a way for others to follow.

America has ventured forth into space for the same reasons. We have undertaken space travel 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 exploration of space has led to advances in weather forecasting, in communications, in computing, search and rescue technology, robotics, and electronics. Our investment in space exploration helped to create our satellite telecommunications network and the Global Positioning System. Medical technologies that help prolong life -- such as the imaging processing used in CAT scanners and MRI machines -- trace their origins to technology engineered for the use in space.

Our current programs and vehicles for exploring space have brought us far and they have served us well. The Space Shuttle has flown more than a hundred missions. It has been used to conduct important research and to

increase the sum of human knowledge. Shuttle crews, and the scientists and engineers who support them, have helped to build the International Space Station.

Telescopes -- including those in space -- have revealed more than 100 planets in the last decade alone. Probes have shown us stunning images of the rings of Saturn and the outer planets of our solar system. Robotic explorers have found evidence of water -- a key ingredient for life -- on Mars and on the moons of Jupiter. At this very hour, the Mars Exploration Rover Spirit is searching for evidence of life beyond the Earth.

Yet for all these successes, much remains for us to explore and to learn. In the past 30 years, no human being has set foot on another world, or ventured farther upward into space than 386 miles -- roughly the distance from Washington, D.C. to Boston, Massachusetts. America has not developed a new vehicle to advance human exploration in space in nearly a quarter century. It is time for America to take the next steps.

Today I announce a new plan to explore space and extend a human presence across our solar system. We will begin the effort quickly, using existing programs and personnel. We'll make steady progress -- one mission, one voyage, one landing at a time.

Our first goal is to complete the International Space Station by 2010. We will finish what we have started, we will meet our obligations to our 15 international partners on this project. We will focus our future research aboard the station on the long-term effects of space travel on human biology. The environment of space is hostile to human beings. Radiation and weightlessness pose dangers to human health, and we have much to learn about their long-term effects before human crews can venture through the vast voids of space for months at a time. Research on board the station and here on Earth will help us better understand and overcome the obstacles that limit exploration. Through these efforts we will develop the skills and techniques necessary to sustain further space exploration.

To meet this goal, we will return the Space Shuttle to flight as soon as possible, consistent with safety concerns and the recommendations of the Columbia Accident Investigation Board. The Shuttle's chief purpose over the next several years will be to help finish assembly of the International Space Station. In 2010, the Space Shuttle -- after nearly 30 years of duty -- will be retired from service.

Our second goal is to develop and test a new spacecraft, the Crew Exploration Vehicle, by 2008, and to conduct the first manned mission no later than 2014. The Crew Exploration Vehicle will be capable of ferrying astronauts and scientists to the Space Station after the shuttle is retired. But the main purpose of this spacecraft will be to carry astronauts beyond our orbit to other worlds. This will be the first spacecraft of its kind since the Apollo Command Module.

Our third goal is to return to the moon by 2020, as the launching point for missions beyond. Beginning no later than 2008, we will send a series of robotic missions to the lunar surface to research and prepare for future human exploration. Using the Crew Exploration Vehicle, we will undertake extended human missions to the moon as early as 2015, with the goal of living and working there for increasingly extended periods. Eugene Cernan, who is with us today -- the last man to set foot on the lunar surface -- said this as he left: "We leave as we came, and God willing as we shall return, with peace and hope for all mankind." America will make those words come true. (Applause.)

Returning to the moon is an important step for our space program. Establishing an extended human presence on the moon could vastly reduce the costs of further space exploration, making possible ever more ambitious missions. Lifting heavy spacecraft and fuel out of the Earth's gravity is expensive. Spacecraft assembled and provisioned on the moon could escape its far lower gravity using far less energy, and thus, far less cost. Also, the moon is home to abundant resources. Its soil contains raw materials that might be harvested and processed into rocket fuel or breathable air. We can use our time on the moon to develop and test new approaches and technologies and systems that will allow us to function in other, more challenging environments. The moon is a logical step toward further progress and achievement.

With the experience and knowledge gained on the moon, we will then be ready to take the next steps of space exploration: human missions to Mars and to worlds beyond. (Applause.) Robotic missions will serve as trailblazers -- the advanced guard to the unknown. Probes, landers and other vehicles of this kind continue to prove their worth, sending spectacular images and vast amounts of data back to Earth. Yet the human thirst for

knowledge ultimately cannot be satisfied by even the most vivid pictures, or the most detailed measurements. We need to see and examine and touch for ourselves. And only human beings are capable of adapting to the inevitable uncertainties posed by space travel.

As our knowledge improves, we'll develop new power generation propulsion, life support, and other systems that can support more distant travels. We do not know where this journey will end, yet we know this: human beings are headed into the cosmos. (Applause.)

And along this journey we'll make many technological breakthroughs. We don't know yet what those breakthroughs will be, but we can be certain they'll come, and that our efforts will be repaid many times over. We may discover resources on the moon or Mars that will boggle the imagination, that will test our limits to dream. And the fascination generated by further exploration will inspire our young people to study math, and science, and engineering and create a new generation of innovators and pioneers.

This will be a great and unifying mission for NASA, and we know that you'll achieve it. I have directed Administrator O'Keefe to review all of NASA's current space flight and exploration activities and direct them toward the goals I have outlined. I will also form a commission of private and public sector experts to advise on implementing the vision that I've outlined today. This commission will report to me within four months of its first meeting. I'm today naming former Secretary of the Air Force, Pete Aldridge, to be the Chair of the Commission. (Applause.) Thank you for being here today, Pete. He has tremendous experience in the Department of Defense and the aerospace industry. He is going to begin this important work right away.

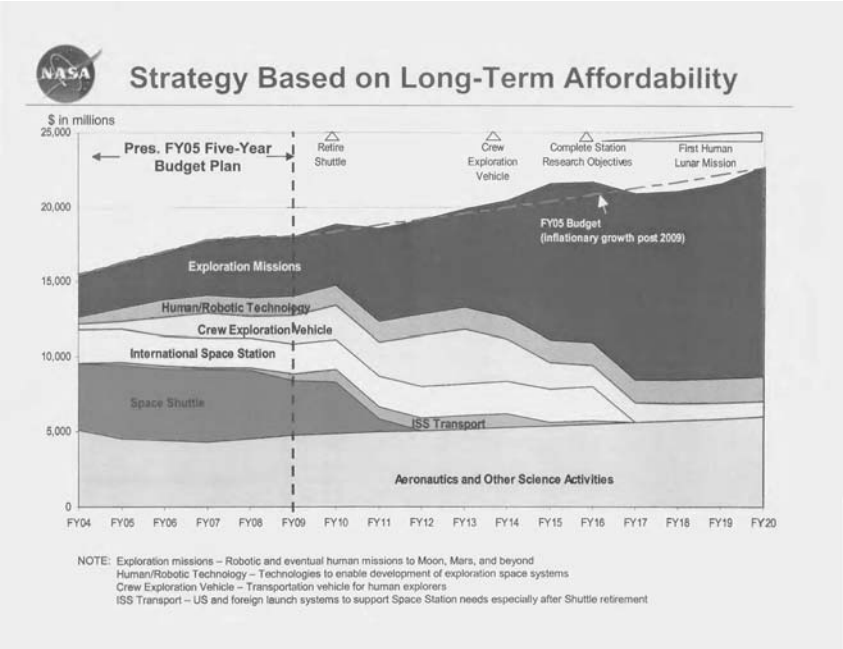
We'll invite other nations to share the challenges and opportunities of this new era of discovery. The vision I outline today is a journey, not a race, and I call on other nations to join us on this journey, in a spirit of cooperation and friendship.

Achieving these goals requires a long-term commitment. NASA's current five-year budget is $86 billion. Most of the funding we need for the new endeavors will come from reallocating $11 billion within that budget. We need some new resources, however. I will call upon Congress to increase NASA's budget by roughly a billion dollars, spread out over the next five years. This increase, along with refocusing of our space agency, is a solid beginning to meet the challenges and the goals we set today. It's only a beginning. Future funding decisions will be guided by the progress we make in achieving our goals.

We begin this venture knowing that space travel brings great risks. The loss of the Space Shuttle Columbia was less than one year ago. Since the beginning of our space program, America has lost 23 astronauts, and one astronaut from an allied nation -- men and women who believed in their mission and accepted the dangers. As one family member said, "The legacy of Columbia must carry on -- for the benefit of our children and yours." The Columbia's crew did not turn away from the challenge, and neither will we. (Applause.)

Mankind is drawn to the heavens for the same reason we were once drawn into unknown lands and across the open sea. We choose to explore space because doing so improves our lives, and lifts our national spirit. So let us continue the journey.

May God bless. (Applause.)


Strategy Based on Long-Term Affordability
$ in millions
25,000
20,000
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Pres. FY05 Five-Year Budget Plan
Retire Shuttle
Crew Exploration Vehicle
Complete Station Research Objectives
First Human Lunar Mission
FY05 Budget (inflationary growth post 2009)
Exploration Missions
Human/Robotic Technology
Crew Exploration Vehicle
International Space Station
Space Shuttle
ISS Transport
Aeronautics and Other Science Activities
FY04 FY05 FY06 FY07 FY08 FY09 FY10 FY11 FY12 FY13 FY14 FY15 FY16 FY17 FY18 FY19 FY20
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

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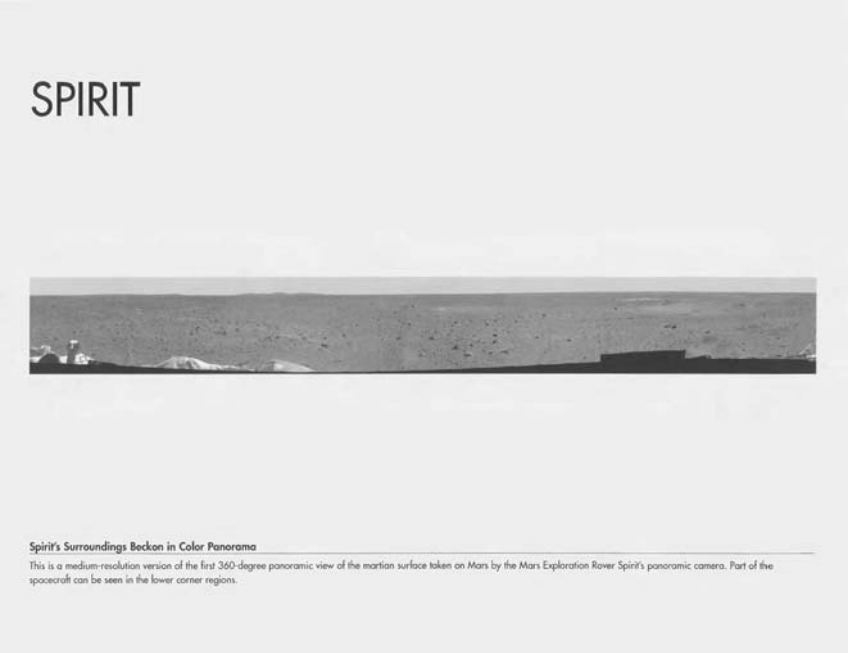
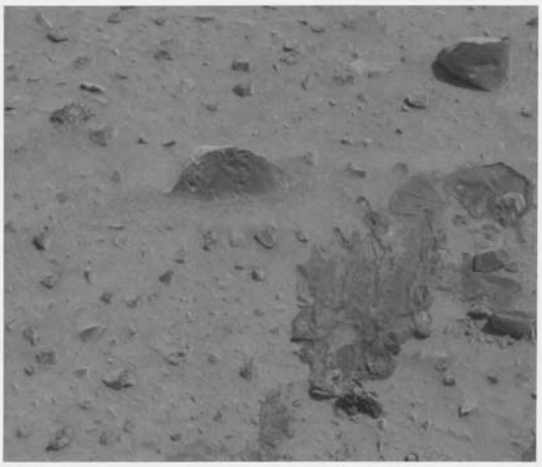

SPIRIT
Spirit's Surroundings Beckon in Color Panorama
This is a medium-resolution version of the first 360-degree panoramic view of the martian surface taken on Mars by the Mars Exploration Rover Spirit's panoramic camera. Part of the spacecraft can be seen in the lower corner regions.

SPIRIT

Spirit Drives to a Rock Called "Adirondack" for Close Inspection

This approximate true-color image taken by the panoramic camera onboard the Mars Exploration Rover Spirit shows "Adirondack," the rover's first target rock.

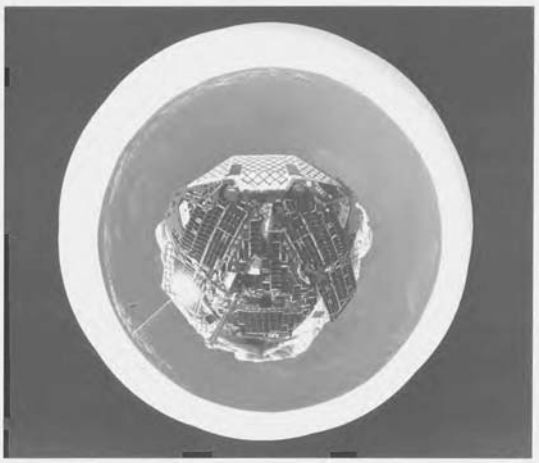
SPIRIT



Airbag Trail Dubbed "Magic Carpet"

The drag mark was made after the rover landed and its airbags were deflated and retracted. Scientists have dubbed the region the "Magic Carpet" after a crumpled portion of the soil that appears to have been peeled away (lower left side of the drag mark).

OPPORTUNITY



Ring Around the Rover

This polar projection of an image from the navigation camera on the Mars Exploration Rover Opportunity shows an overhead perspective of the rover.

OPPORTUNITY

Gear On Opportunity Rover Passes Martian Health Check

The interior of a crater surrounding the Mars Exploration Rover Opportunity is shown. This image was taken soon after the rover's landing.

DON'T DESERT HUBBLE

Robert Zubrin—January 27, 2004

Last week, NASA Administrator Sean O'Keefe announced that he had decided to cancel all future Space Shuttle missions to the Hubble Space Telescope, including SM4, the nearly-ready-to-go flight that would have installed the new Cosmic Origins Spectrograph and Widefield Camera 3 instruments. This decision was announced in conjunction with an overall policy shift by the Bush administration to phase out the Shuttle and International Space Station (ISS) commitments by 2010, thereby clearing the way to redeploy their budgets towards supporting human exploration of the Moon and Mars. While the general redirection of NASA's human spaceflight program from Earth orbital activities towards planetary exploration was a valuable and long-overdue step, canceling the Hubble upgrade mission was a huge mistake.

The Hubble Space Telescope has been the most scientifically productive spacecraft in history. Through Hubble, we have observed directly the planetary cometary impacts that drive the evolution of life, witnessed the birth of stars that make all life possible, and measured the size and age of the universe itself. The astronaut missions that have made this possible stand as epic achievements in the chronicles of humanity's search for truth.

Now we have a chance to push further. The Cosmic Origins Spectrograph and Widefield Camera 3 designed to bring the Hubble to its full potential have already been built and tested at a cost of $167 million, and promise an enormous scientific return upon delivery to orbit. With the help of these instruments, Hubble would be able probe deeper into space and time, helping to reveal the processes that governed the origin of the universe and that will determine its ultimate fate. How can the decision abort such a program possibly be justified?

Certainly not on the basis of cost. If the Bush plan were to stand down the Shuttle immediately, and save the $24 billion required to operate it through 2010 so as to initiate the Moon/Mars program this year with substantial funding, that would be one thing. But given the decision to return the Shuttle to flight, canceling the Hubble upgrade would only save a pittance. It takes about $4 billion per year to maintain the standing army of engineers and technicians that support the Shuttle program, but it only costs an additional $100 million or so to fly five Shuttles in a given year instead of four. Thus the additional cost to the taxpayer to fly both

SM4 and a subsequent flight a few years later to replace the Hubble's batteries and gyros and reboost it to a higher orbit where it could be functional well into the next decade would only be about $200 million, or less than one percent of the Shuttle program's budget over its remaining life. From a financial point of view, the decision to abandon the Hubble upgrade while continuing Shuttle flights amounts to throwing out the baby while keeping the bathwater.

Safety arguments won't wash either; if the Shuttle is safe enough to fly to the ISS, it is safe enough to perform its mission to Hubble. It is true then when flying to the ISS, the crew has a safe-haven on orbit, which is not available to Hubble flights. However Hubble missions leave the Cape flying east-southeast, while launches to ISS go northeast. Thus in the event of a launch abort, Hubble missions can ditch in warm tropical waters while ISS flights must come down in the frigid North Atlantic, where the crew's chances for survival would be much less. Thus, while no true quantitative engineering analysis has been done to establish whether and to what extent Shuttle flights to ISS are more or less risky than Hubble missions, there is good reason to believe that, if anything, it is the latter that offer greater safety.

Furthermore, consider this: Under the new space policy, the President intends to ask Congress to spend billions of dollars to develop technology to enable human Moon and Mars missions. Yet Congress has just spent $167 million to develop the instruments for SM4, only to be told by the NASA Administrator that he is now afraid to fly the Shuttle to deliver them. If such behavior is accepted, what guarantee can lawmakers have that after they spend billions to develop manned Moon or Mars exploration hardware, a future NASA administrator might not also get cold feet? It is difficult to understand how an agency which is too risk-adverse to undertake a Shuttle mission to Hubble could possibly be serious in considering a piloted mission to the Moon or Mars.

The decision to cancel the Hubble mission thus completely undermines the President's call for human planetary exploration. Unless we are willing to accept risks equal to, and in fact significantly greater, than those required to upgrade the space telescope, human explorers are not going to the Moon, Mars, or anywhere else. And if we are not going to engage in human interplanetary travel, then the primary rationale for the Space Station program—learning about the effects of long-duration spaceflight on human physiology must be brought into question as well.

The desertion of Hubble is an offense against science and civilization. It represents a departure from the pioneer spirit, and its ratification as policy would preclude any possibility of a human future in space. It is an inexcusable decision, and it needs to be reversed.

Dr. Robert Zubrin is President of the Mars Society and author of the books *The Case for Mars* (1996), *Entering Space* (1999), and *Mars on Earth* (2003).

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO HON. SEAN O'KEEFE

Question 1. President Bush announced the establishment of the Commission on the Implementation of U.S. Space Exploration Policy to advise NASA on the long-term implementation of his plan. The President stated that the Commission would consist of "public and private sector experts."

Can you elaborate on the role that Mr. Pete Aldridge, who, as I noted in my opening statement, sits on the Board of Lockheed Martin, will have as Chairman of the Commission in determining private sector involvement, including that of Lockheed Martin, in the implementation of the President's proposal?

Answer. The Commission's charter and membership were established by the President by means of an Executive Order, and the Commission will report to the President. NASA's role is limited to providing administrative support and expert advice as requested by the Commission. Questions on the role of specific Commissioners would be appropriate for the White House or the Commission itself.

Question 2. The amount that the President proposes be spent over the next five years on his new space initiative is $12 billion, with $1 billion in new spending and $11 billion to come from reallocating funds from existing programs. What criteria will be used to determine the programs that will be cut, and the amounts of these cuts?

Answer. The new Vision for Space Exploration is designed to fund a robust program of space exploration while maintaining fiscal responsibility, consistent with the Administration's goal of cutting the budget deficit in half within the next five years. NASA's FY 2005 Budget will increase by $1 billion over five years when com-

pared with the President's 2004 plan. In addition to the new funding, the vision will be supported by $11 billion in reprogrammed funds over the next five years.

The majority of the $11 billion reallocation, $8 billion over five years, comes from human space flight-related programs. These include:

Discontinue Space Launch Initiative ($5.9 billion over five years)—The vision puts emphasis on enabling the exploration of other worlds, including necessary transportation systems. The vehicles that would have been developed under the Space Launch Initiative were focused on improving the transport of crew and cargo to and from the Space Station. These activities are discontinued in favor of Project Constellation, which will develop a crew exploration vehicle to enable human exploration missions beyond low Earth orbit.

Space Shuttle Retirement ($1.5 billion over five years)—The vision sets a goal of completing Space Station deployment, planned for the end of the decade. With its Space Station deployment job finished, NASA will retire the Space Shuttle to enable safer approaches to crew transport and to redirect resources towards exploration goals. The five-year projection in the FY 2005 budget assumes savings from Space Shuttle retirement beginning in FY 2008.

Space Station Research Redirection ($1.2 billion over five years)—The vision refocuses the Space Station on research to enable human exploration of other worlds. NASA has set a goal of finishing this research by 2016. The budget eliminates some Space Station research not tied to exploration needs and redirects resources towards research areas required for exploration.

Other reductions ($3 billion over five years) come from lower priority programs that are not elements of the vision. These include:

New Start Deferrals and Level Spending ($2.7 billion over five years)—The FY 2005 budget defers the start of new flight projects, such as the Global Precipitation Mission, Solar Terrestrial Probes, and Beyond Einstein, by one or two years. The budget also sustains spending levels at current rates in related Earth Science and Space Science program areas.

Reduce Space Technology and Defer New Facilities ($300 million over five years)—The budget adjusts space technology funding, aligns remaining space technology activities with exploration needs, and defers construction starts of new facilities until exploration needs can be incorporated in facilities planning.

The table below summarizes the reductions that make up the $11 billion redirection.

($ in billions)	2005	2006	2007	2008	2009	Total
Discontinue Space Launch Initiative	-0.8	-1.2	-1.3	-1.2	-1.4	-5.9
Space Shuttle Retirement	0.0	0.0	0.0	-0.2	-1.3	-1.5
Redirect Space Station Research	-0.1	-0.2	-0.3	-0.3	-0.3	-1.2
Human Space Flight-Related Reductions	**-0.9**	**-1.4**	**-1.6**	**-1.7**	**-3.0**	**-8.6**
Defer New Mission Starts and Level Spending	-0.2	-0.5	-0.7	-0.7	-0.6	-2.7
Reduce Space Tech & Defer New Facilities	-0.15	-0.03	-0.04	-0.05	-0.07	-0.3
Other Reductions	**-0.3**	**-0.5**	**-0.7**	**-0.8**	**-0.7**	**-3.0**
TOTAL REDUCTIONS	**-1.3**	**-1.9**	**-2.3**	**-2.5**	**-3.7**	**-11.6**

Question 2a. How will NASA ensure that these funding cuts will not adversely impact NASA's overall mission, including the safety of the shuttles and the International Space Station?

Answer. The FY 2005 budget and associated five-year budget projection help ensure Space Station and Space Shuttle safety and mission success while also planning for Space Shuttle retirement when its role in Space Station deployment is complete, planned for the end of the decade.

The FY 2005 budget provides $4.3 billion for the Space Shuttle, a 9 percent increase above FY 2004. The budget also provides an increase of $700 million for the Space Shuttle through FY 2007, including $200 million in FY 2005 for return-to-flight activities. The budget assumes savings from Space Shuttle only when Shuttle retirement draws near and Shuttle activities would begin to phase out, beginning in FY 2008.

The FY 2005 budget provides $1.9 billion for the Space Station, a 24 percent increase above FY 2004, primarily due to $140 million for new Station crew and cargo services, and $100 million for forward funding of Station reserves to compensate for a $200 million appropriations cut in FY 2004.

Question 3. The General Accounting Office (GAO) recently reported that NASA is having difficulty meeting its own financial management goals. In light of GAO's findings regarding financial management controls at NASA, should we be concerned about NASA's ability to manage new programs?

Answer. Improving NASA's financial management is a high priority. A major part of this undertaking was the implementation of an agency-wide Integrated Financial Management system, and the retiring of 72 disparate and incompatible accounting systems. We now have financial visibility across the agency with the push of a button. This effort was necessary to better manage our existing programs, and will help us manage and meet the New Vision for Space Exploration.

Background

GAO and OMB have called for agencies to improve their financial management in part by using integrated off-the-shelf enterprise software. The deployment of our new integrated financial management system is proceeding on schedule, as well as within scope and cost parameters described in our April 2003 report to Congress on the Integrated Financial Management system. We have been careful to incorporate the most recent recommendations from the GAO, and have been fully operational agency-wide on the new system since the beginning of the current fiscal year (October 2003).

NASA faced the extraordinary challenge of bringing this new system online while attempting to meet an accelerated timeline in producing its annual financial statements. When considering the alternative implementation strategies, we considered two basic options: (1) bring on the new system and produce our financial statements using the old legacy systems, or (2) bring on the new system in time to have it produce the statements. The first approach required *two* Herculean efforts, while the second required one. Since producing financial statements under the disparate legacy systems was already a challenge that relied a great deal on painstaking manual reconciliations, we decided on the latter strategy, which was admittedly aggressive. In the end, it proved to be too much to accomplish in a single year. Nevertheless, we are online with a unified system and are in a better position not only to meet the new requirements to produce quarterly statements, but also meet the challenges set forth by the President.

Our delay in delivering this information resulted in a disclaimer from our auditors for FY 2003. Frankly, this disclaimed opinion accurately reflected the sheer magnitude and complexity of the agency-wide conversion process to our new financial system. For example, the phased conversion process required the audit to be performed on both the legacy systems and the new system using a "cross walk" for reconciliations. This complexity and the volume of accounting data that had to be converted created a significant delay in delivering our financial statements and related financial information to our auditors (they were delivered on December 10).

By June 2003, we had deployed this single integrated system in all of our Centers, allowing us to retire approximately 72 separate and incompatible accounting systems across the Agency and "clean" up about 12 years of financial data (several million entries). Our focus now is on stabilizing this new system under full operational conditions, learning how to optimize it capabilities, perfecting the training of our several thousand users, and fixing remaining "bugs" which could only be identified under fully operational conditions.

For 2004, given the recent conversion to our new system, we are managing our audit as a full-blown project rather than as a regular process, assigning to the task to a dedicated team of both accountants and system experts reporting directly to the Deputy Administrator and the Agency CFO. Additionally, we have converted the entire agency to a full cost accounting environment to better track and analyze the costs of individual projects and programs. This innovation led to NASA receiving an honorable mention at the President's Quality Award ceremony recognizing best practices in budget and performance integration.

Question 4. As part of the Administration's roll out of the new program, Senate staffers were briefed on the plan by staff from the National Security Council. Are there any national security or military components to the new space program?

Answer. The fundamental goal of the Vision for Space Exploration is "to advance U.S. scientific, security, and economic interests through a robust space exploration program." The vision does not have any specific national security or military components, and the President's budget submission for NASA for FY05 does not contain any such new vision-related initiatives. NASA and the Department of Defense routinely consult at senior levels and cooperate to meet common requirements, and these practices will continue as we implement the Vision for Space Exploration.

Question 4a. If so, will the Department of Defense contribute funding to this new program?

Answer. No DoD contributions to the Vision for Space Exploration have been identified or sought. DoD and the commercial sector may develop future Earth-to-orbit launch systems, with NASA as a capability purchaser rather than a developer, unless NASA has a unique requirement that cannot be satisfied by those sources.

Question 5. In your written testimony you state, "the budget strategy will *not* require large balloon payments by future Congresses and Administrations." Considering our experience with the International Space Station, what assurances can you give us that enormous cost overruns that require these balloon-type payments won't happen again?

Answer. The pacing and phasing of the activities laid out in the NASA budget strategy are fiscally responsible and, by design, will not require any large balloon payments. With regard to past ISS overruns, we have instituted many management reforms that have worked well to get spending under control. We will apply these lessons learned to future activities encompassed by the Vision for Space Exploration.

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. 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 the President's 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 without the need for large balloon-type payments.

Question 6. The President's space proposal calls for completing the International Space Station (ISS) by 2010 and terminating Shuttle operation in 2010. What are NASA's plans for servicing the ISS operations after 2010 and before 2014 when the President proposes to have the Crew Exploration Vehicle available?

Answer. Based upon President Bush's directive to phase out the Shuttle once the ISS assembly is complete, planned for the end of the decade, NASA is re-assessing the ISS final configuration, logistics, maintenance, and utilization upmass and downmass requirements in coordination with the International Partners. This re-assessment includes both pressurized and unpressurized cargo and will revisit research requirements in light of the Vision for Space Exploration. The ISS Program, with the International Partners, will develop a plan for meeting the revised cargo requirements through existing vehicles, those approved for development by our Partners, and through the potential purchase of commercial supply and return services. Current and planned international partner vehicles include Russian Soyuz and Progress vehicles, the European Automated Transfer Vehicle, and the Japanese H–II Transfer Vehicle. Commercial cargo transport services will also be considered. Use of the new Crew Exploration Vehicle may also be examined.

Question 7. The overall projected budget for the new space proposal is $12 billion for the next five years, which includes the design, development and operation of the Crew Exploration Vehicle. The total cost for the Orbital Space Plane (OSP) now on the drawing boards had been estimated at more than $15 billion. Can you explain how NASA can afford to implement a comprehensive Moon-Mars space program for less than the cost of the OSP—a vehicle intended exclusively to service the International Space Station?

Answer. Implementing the Vision for Space Exploration is a multi-decade endeavor. Where the OSP had been proposed to be completing development within the horizon of the President's budget, only the first five years of the exploration vision are covered by the budget. In order to leverage its investment in the OSP Program, NASA will conduct a full review of OSP's management and technology with an eye towards applying the past work of the Orbital Space Plane Program to Crew Exploration Vehicle (CEV) development. The CEV will be designed for simplicity and robustness. NASA has made great strides in bringing its programs' costs under control. The International Space Station, for example, has implemented management reforms that have moved the program onto sound financial footing. The CEV will be developed at a deliberate pace, one step at a time, learning and improving with a first test flight before the end of the decade and the first crewed mission targeted for 2014. Most of the large-scale development for the CEV will be conducted using funding freed up by the retirement of the Shuttle, planned for the end of the decade.

For the CEV and other exploration systems, 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. 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 the President's priorities.

Question 8. The most recent Interim Report of the Return to Flight Task Group states that "Detailed plans for many of the recommendations have not been forthcoming. NASA has not been timely in some of their responses to Task Group requests for information." Given the need for a safe and timely return to flight, such reports of questionable cooperation from NASA are disconcerting.

Please comment on NASA's cooperation with information requests from the Return to Flight Task Group.

Answer. NASA intends to cooperate fully and openly with the Return to Flight Task Group. Nearly all of the technical information requests from the Return to Flight Task Group have been fulfilled. Many requests for information were in the areas of management, organizational, and cultural changes. These critical areas under consideration by NASA have been deliberately debated and scrutinized within NASA to make certain that there are no unintended consequences of our proposed actions.

NASA officials met with members of the Task Group during a fact-finding meeting in late February. During the meeting, NASA provided updates on several products and responded to many of the Task Group's actions. Public discussion and recommendations are expected during the Task Group's upcoming plenary meeting on April 24–25.

Question 9. Could you please explain your rationale for canceling the servicing mission for the Hubble Space Telescope:

Answer. The difficult decision to forego a Space Shuttle mission dedicated to the fifth on-orbit servicing of the Hubble Space Telescope (HST) was arrived at only after a thorough consideration of the report from the Columbia Accident Investigation Board, potential risks and safety concerns for the astronauts, and the current and expected health of the telescope. The primary driver for this decision was safety, not budget.

If NASA had decided to pursue the fifth servicing mission, at a minimum our plan to satisfy CAIB recommendation 6.4–1 (regarding TPS Inspection and Repair Capabilities) would require:

- Development of an autonomous repair capability (*i.e.,* one independent of the International Space Station) using an instrumented boom "carried" by the Shuttle Remote Manipulator System to inspect for damage on flight day two to the Thermal Protection System and Reinforced Carbon-Carbon wing leading edge.
- A second orbiter and crew ready, on the launch pad, in the event of a problem preventing the safe return of the SM 4 orbiter.
- A rescue capability requiring the free-flight exchange of personnel between the two orbital vehicles and an understanding of the problems on the first vehicle such that risking additional personnel on the rescue vehicle would be justified.

In addition, the new inspection and "second Shuttle" technologies and procedures would be developed for a *one-time* use for HST servicing. This is because Hubble's unique orbital inclination (28 degrees) is not compatible with that of the International Space Station (ISS, which orbits at a 51-degree inclination); the new launch/mission safety procedures assume Shuttle access to ISS.

The return-to-flight manifest has not been firmly established yet; however, for planning purposes, it was decided that the earliest SM–4 could be manifested was mid-2006; 2007 represented a more likely scenario.

HST is operating normally and will continue to function until age and natural wear take their inevitable toll on its components; current predictions estimate that the observatory will continue to operate until 2007–08. Since the likely launch date and the predicted end of HST science operations are so close, there is a significant possibility that the observatory will no longer be operational at the time of the mission.

NASA is aggressively looking for innovative ways to extend the science lifetime of Hubble as far as possible. There is enough HST data (already existing and yet to come) to keep researchers busy for years to come. We are planning a robotic mission to de-orbit the observatory safely once it can no longer conduct world-class science.

Question 10. Your testimony claims that $4 billion will be freed up for the President's new space initiative by retiring the Space Shuttle. Based on the CAIB report's description of how previous transfers from the Space Shuttle account led to

cost pressures that contributed to the *Columbia* accident, how do you intend to ensure the shuttles' safety while making these cuts?

Answer. We are applying the lessons learned from the CAIB into the return to flight plan for the Space Shuttle and are committed to flying safely until the Shuttle is retired. The FY 2005 President's request adds approximately $690 million more to the Space Shuttle budget through FY 2007 compared to the FY 2004 President's budget request and covers the critical years of the International Space Station assembly. Reductions in the Shuttle budget start only in FY 2008, as hardware production is phased-down.

Question 11. Public response to the President's announcement has been lukewarm. A Time/CNN poll reports that about 62 percent of Americans disapprove of the President's plan. The Associated Press poll reports that 55 percent say they would prefer spending funds on other programs. Why do you think the public has not been more enthusiastic?

Answer. Polling data over time indicate broad public support for space exploration. Given the recent timing of the President's announcement, many mistaken notions about the cost and goals of the program are still widespread. The extraordinary public fascination with the results of the current Mars Exploration Rover missions attests that, when results are visible and long-range plans become present realities of discovery and exploration, the public is enthusiastic, supportive, and inspired.

Question 12. The Orbital Space Plane (OSP) was intended to serve as a "lifeboat" for astronauts, and be attached to the International Space Station (ISS). The President has proposed that the Crew Exploration Vehicle (CEV) be able to transport crew to the ISS.

(a) Will the CEV also have the capacity to serve as a "lifeboat" for astronauts?

Answer. The CEV program is a new initiative focused on a different set of requirements than the OSP program. The CEV will be developed for missions beyond low Earth orbit. It may be able to perform some crew transfer functions that the OSP would have performed, but the emphasis in CEV design will be centered on exploration. Decisions will be made so that the CEV design assures the safety of human crews and the sustainability of future exploration.

Question 12b. Will NASA initiate a new procurement process for the CEV or will NASA continue with a revised OSP process?

Answer. NASA will initiate a new procurement process. NASA is committed to making full and open competition a hallmark of the CEV program. By the end of the summer of 2004, the Office of Exploration Systems will define Level 1 requirements for the CEV program in preparation for the issuance of an RFP for concept development in the fall of 2004.

Question 13. Part of the President's plan called for going to the Moon. We landed on the Moon 35 years ago. How much of the technology that was used during the Apollo missions will be used for the return mission?

Answer. We will seek to use all past exploration experience as we move forward to implement the new Vision for Space Exploration. There has been significant technology development since we first landed on the Moon 35 years ago. However, at this early stage of program development it is too early to quantify what, if any, of the past technologies used during the Apollo missions would be used for future missions.

Question 14. You have chosen retired U.S. Navy Rear Admiral Craig Steidle to head the new Exploration Systems Enterprise. RADM Steidle was the former manager of the Defense Department's Joint Strike Fighter program. Do you envision that the CEV will be developed using the competitive prototype approach used to award a contract for the Joint Strike Fighter?

Answer. NASA's Office of Exploration Systems will utilize a number of the best practices that were developed in the Joint Strike Fighter program as well as other Defense Department initiatives. Among those are the spiral development approach to program phasing, which emphasizes incremental evolution based on demonstrated systems performance, and the formulation of acquisition strategies that maximize full and open competition between private sector teams.

Question 15. In your written testimony, you have stated that NASA "will be making decisions on how to best implement new programs," some of which "will not be easy." Could you please describe what some of these decisions are?

Answer. To implement the new exploration vision, a number of key NASA program and institutional realignments will have to be undertaken. Examples include:

- *Space Station Research*—Refocusing plans for research aboard the Space Station, as well as other Biological and Physical Research, to understand factors

affecting astronaut health on long-duration voyages into deep space and to other worlds and develop appropriate countermeasures, life support, and other systems.

- *Space Transportation*—Transitioning from the Orbital Space Plane (OSP) and Next Generation Launch Technology (NGLT) programs to the Crew Exploration Vehicle (Project Constellation).
- *Space Technology Research*—Realigning technology development in the Mission and Science Measurement program theme to support future exploration system needs.

Question 16. The James Webb Space Telescope (JWST) is a proposed orbiting infrared observatory that is expected to replace the Hubble Space Telescope (HST) at the end of the decade. How will the President's new space agenda affect plans to develop the James Webb Space Telescope?

Answer. The James Webb Space Telescope continues to be a priority for NASA, and it dovetails well with the President's new space agenda. As the cornerstone mission for NASA's Astronomical Search for Origins science theme in the next decade, JWST will search for extrasolar planets, some of which may boast habitable environments. This effort supports the *Renewed Spirit of Discovery: The President's Vision for U.S. Space Exploration,* which calls for the implementation of a human and robotic program to explore the solar system and beyond. JWST is also the number one priority for the astronomical community, as noted in the National Academy of Sciences' Decadal Survey released last year.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. FRANK R. LAUTENBERG TO HON. SEAN O'KEEFE

Question 1. You mentioned in your testimony that NASA will comply with the Columbia Accident Investigation Board's recommendations prior to returning to flight. Does NASA have a plan for complying with all of the CAIB's recommendations? If so, how long will it take to implement, and at what cost?

Answer. On September 8, 2003, NASA submitted to the Committee a copy of the Agency's preliminary Implementation Plan for Return to Flight and beyond. Updates to the Plan have been provided to the Committee on October 15, 2003, November 20, 2003, and most recently on January 30, 2004. This Plan addresses NASA implementation strategy for complying with each of the 29 CAIB recommendations and will be periodically updated as progress is made or as issues arise. All updates to the Plan are provided to the Committee.

The plan lists preliminary schedule and cost estimates for implementing each CAIB recommendation. These estimates will be revised as NASA refines all of the activities necessary to respond to the recommendations. Because these activities are in various stages of maturity, cost estimates represent only those activities that have been approved for implementation and funded by the Space Shuttle Program. NASA intends to implement all of the recommendations categorized as "Return to Flight" prior to resuming operations of the Space Shuttle.

Question 2. Did the Administration consult with space officials from foreign governments before developing the new space proposal? Did you meet with any representatives from China, the European Space Commission, Japan, or any other country with a developed space program or our foreign partners for the purpose of gaining assistance with developing the President's proposal?

Answer. Key foreign governments with space programs, including the International Space Station partners, China, and India, as well as close allies such as Australia, the United Kingdom, and Israel, were notified in advance of the President's announcement. NASA maintains extensive contacts with foreign space agencies and has followed up the President's announcement with additional briefings. The vision specifies a role for international cooperation in exploration, which NASA will pursue.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO DR. LOUIS FRIEDMAN

Question 1. In your written testimony, you expressed great much enthusiasm about the potential benefits that could be achieved from having an outpost on Mars.

(a) What benefits do believe can be achieved from an outpost on Mars?

Answer. A Mars Outpost can be a meaningful goal for robotic exploration—a focus for disparate scientific and technical objectives. Geologic, geochemical, atmospheric,

environmental measurements, in-situ resource utilization pilot development, navigation aids (beacons) and communications infrastructure can all be set up as part of the Mars Outpost. The robotic program is served by each of these, and preparations are begun for the humans.

It would be a publicly exciting project-development and monitoring of the martian outpost. People, especially children, around the world could watch (and ultimately even interact on computers with) the landing site development on Mars-from a few simple robots to a base for human operations.

Human mission costs would be lowered and more reliable because of the infrastructure and robotic preparations. By the time humans actually landed there a lot of the cost and support would be borne.

(b) Does this enthusiasm extend to an outpost on the Moon as proposed by the President?

Answer. The Moon has been explored a lot, with robot spacecraft and with humans, and there is no compelling question for humans there (the questions of life, or of our evolution as a multi planet species). A lunar outpost as an goal might be seen publicly as for dubious or trivial purpose. The image of playing golf on the Moon might be what it recreates. That is one reason the Apollo program ended. However if an outpost on the Moon was a prototype or preparation for the Martian outpost, a temporary practice area, that might be valid, both technically and with the public, because it would be an engineering step-as was Gemini to Apollo.

Question 2. It has been reported that the President's proposal will cost between $170 billion and $600 billion. Yet the President has only proposed providing $12 billion over the next 5 years.

(a) Do you agree with the reported cost estimates?

Answer. I have little basis for an independent cost estimate. I do not know where this range has come from, or what assumptions went into it. The President's proposal is in one sense open-ended; even though it has specific objectives along the way, which can be costed. But, extending human presence into the solar system is not something that admits a total cost estimate. I agree that the five year cost estimate should include only those specific programs that have been approved for starting down the path of sending humans to Mars—and have no reason to disagree with the $12 billion estimate for that. Later programs, including the sending of humans to the Moon and Mars will be costed by building on the experience and accomplishments of the earlier steps. As a guess, I would say the incremental decision necessary by the Congress for sending humans to Mars should be in the range of $50 billion to within a factor of two ($25–95 billion.)

(b) Do you believe that $12 billion is sufficient funding to start the new programs proposed by the President and still meet the goals he has laid out for travel to the Moon and Mars?

Answer. Again, I have no basis for independent cost analysis. But, I believe it is reasonable, and the proper way to begin. The five-year programs involve a major redirection for NASA; it is better to do that with a limited budget, than with an open-ended one. That will help force the changes. Hopefully, after that the experience and accomplishments will make the next steps affordable.

(c) Are you aware on any factors that could significantly increase the cost of this proposal that are not currently being considered?

Answer. There are many. Chief among them are bad management, lack of focus on the goal of sending humans to Mars and/or introduction of spurious additional objectives that detour the program. This can happen for example when the program is made to serve scientific, technological or geographical or other political constituencies with new objectives not otherwise serving the main goal. Others have said that the current NASA organization is not up to this task and will inflate the costs either to increase funding or to resist changes. I agree that changes in NASA will have to be made but I would not assert that they cannot be made.

Question 3. Can you expand on your written statements regarding the ways international collaboration on the Moon-Mars mission may benefit the United States space exploration program?

(a) What lessons should we apply from on our experience with the International Space Station to an international partnership for our further exploration of space?

Answer. The space station was enabled and saved by international cooperation. Until 1994 (when at that point despite a decade of program existence it was still only a paper concept) it had neither the political support or technical robustness to be developed. When the Russians were brought in, hardware and accomplishments in the program began to proceed rapidly—even with some enormous practical prob-

lems. Currently we rely on international cooperation for maintenance and access to the space station.

International cooperation increase the political base of big projects and provides a wider range of assets for their success. It can reduce costs, although in some cases that is offset by increased complexity. The main benefit is being able to achieve more, and provide more options for the success of complex projects.

In the case of the new space policy other countries might be able to do particular precursor missions, add to technical developments and contribute specific systems and sub-systems for the many parts of the Moon and Mars programs. Additionally a broad international public interest will provide resiliency to the program as well as expanding the public educational and scientific benefits.

Question 4. You have advocated the establishment of robotic Mars outposts as a strategy for avoiding the personnel risk and increased costs associated with human exploration of Mars.

(a) How will these robotic outposts on Mars reduce cost?

Answer. Robotic Mars Outposts will set up infrastructure like navigation beacons, communications systems, and in-situ resource utilization for future human missions. They will also provide extensive surveys of the eventual landing areas for humans, preparing them and making the exploration tasks more efficient.

(b) Do you think the establishment of outposts on the Moon is an essential step to a successful mission to Mars?

Answer. No, I do not think a lunar outpost is necessary for a successful Mars mission. The moon is very different, and has few of the characteristics that can really help prepare for Mars missions. One important exception that might mitigate this assertion is the value of practicing various engineering and human work activities at a closer location. I have always thought this could be done more cheaply on Earth, but I admit that there may be some argument for doing such practice activity on the Moon. NASA should study it, but they should consider the cost and the effect on the overall Mars mission plans when they do so. If lunar activities do make sense, it certainly would not be in the form of permanent presence on the Moon—that would bog us down on the Moon and delay any Mars mission planning.

If we conduct Moon missions as a preparation for Mars missions, they should be temporary and limited.

Question 5. At a hearing last year on Lunar Exploration, the Committee heard testimony that the Moon could be used as a resource for solar power, or for mining the isotope Helium-3. What are your thoughts on these proposals?

Answer. The answer has three parts: (1) resources for Earthly use, (2) resources for lunar use and (3) resources for Martian use. But even before considering those separately, let us note that solar power has been found to very uneconomical on Earth. Imagine the lunar cost-it would be enormous. And, fusion power has not even be invented yet for Earthly applications, so finding a fuel source for it (even if were cheap) is no basis for a program decision.

I cannot imagine a day when lunar resources would have any Earthly use as an energy source. Costs of transporting things to the Moon to create incredibly hard-to-manufacture devices there to then transport as energy back to the Earth seems obviously much more expensive compared to finding Earthly alternatives.

Making energy on the Moon for lunar use might be economically feasible depending on what the economic justification is for having power on the Moon in the first place. Science fiction scenarios of lunar cities could economically employ lunar power sources, I suppose; but what economic rationale would there be for the lunar city? For all applications I can conceive it would be far more economical to bring a few nuclear reactors to the Moon, than to try to bring the material necessary to make a lunar manufacturing plant.

Using lunar resources for Martian exploration is as impractical as using it for Earthly applications. In addition to having to bring everything to the Moon to extract and then manufacture resources, you now would have to bring it out of the lunar gravity to send it to Mars. Mars has easily accessible oxygen and other molecules for fuel production—the Moon does not. Mars, with high likelihood, has water that is reasonably accessible. The Moon does not (any isolated patches of ice will certainly be located in hard to reach places, and of very low density of water molecules). So it will always be easier to solve Martian resource use with a combination of Earth and Mars resources than trying to extract anything out of the Moon.

Question 6. In your written testimony, you state that a permanent lunar base could make the Martian exploration program "prohibitively" more expensive. Yet as proposed by the President, a going back to the lunar surface is integral step to the to development and testing of new approaches, systems, and technologies for Mars

exploration. What are your thoughts on the cost versus the benefits of going back to the lunar surface?

Answer. Cost vs. benefit should certainly be studied. I stated in answers to earlier questions my concerns and skepticism about lunar activities in support of Mars missions. While some lunar activities might help, constructing a permanent lunar presence or developing a lunar outpost for hypothetical use of lunar resources would add enormous additional and unnecessary costs and schedule to sending humans to Mars.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO NEAL LANE

Question 1. In your testimony, you outline the many contributions to space science made by NASA. In particular, you highlight the value of NASA's space-based astronomical telescopes. There have been reports of NASA discontinuing service missions to and phasing out the Hubble Space Telescope to preserve funds for the new Moon-Mars mission. What do you think is the long-term impact of such funding strategies on space science?

Answer. There are many important scientific facilities and robotic missions already planned and others not yet conceived. These unmanned missions are by far the most cost effective way to do science. My concern is not only that money needed for human space exploration would erode the science budgets, especially given the need for substantial reallocations of money within the NASA budget, but also the fact that science and exploration are easily confused in most people's minds. It is disappointing that a decision has been made to terminate the enormously successful Hubble Space Telescope, and a planned servicing mission has been cancelled. NASA's space science can not only provide the information needed for missions proposed in the next few decade, but it also can be a valuable source of information to help lead the country and the world into new ventures in the future. Canceling highly successful programs, such as the Hubble Space Telescope, might seem to help with current budget problems, but in the long run, NASA and the astronomy community will miss out on important scientific discoveries. It is precisely this kind of tradeoff between science and human spaceflight that I warned the Committee about in my testimony. The decision does not bode well for the future of NASA and the space program.

Question 2. How do you think universities will be impacted by the shift in funding priorities at NASA in order to cover the costs of the Moon-Mars mission? Will it lead to an increase in Congressional earmarking as universities fight over a smaller pot of money?

Answer. I believe that NASA has been given an ambitious spaceflight agenda and high expectations without the necessary commitment to fund it. Recognizing that science has been the heart and soul of NASA, I am confident that the agency will attempt to protect science while moving forward with this bold plan, but science should be enhanced not protected. Moreover, as realistic cost estimates are developed and corresponding budget requests made to the Administration and Congress, NASA science will suffer. Science will not be able to compete with the momentum of an ambitious human spaceflight agenda that will demand that schedules are met and contracts honored. There will be new opportunities for research related to the goals of the human spaceflight program, in particular the long-term effects of zero-gravity and other conditions of living in space on human beings. However, most NASA-supported researchers do not work in the area of human physiology and psychology. There will also be important work to be done in engineering and technological development.

With regard to earmarking, the trend already is toward more, not less. As funds get tight and NASA begins to reallocate funds among fields, cutting some programs expanding others, more earmarking is inevitable. I stated in my testimony that in order for NASA to stand any chance of being successful with the new goals the President has outlined, the Administrator must be given the opportunity to truly manage the agency, look for efficiencies, streamline programs and responsibilities, and fund those projects that enhance its mission—science, human spaceflight, and aeronautics—without having the constraints of excessive earmarked spending and interference with administrative decisions.

Question 3. In your testimony, you stated "Any considerations of a change in national space policy should insure the continued health of NASA's space science programs." Do you think the Moon-Mars mission as currently presented accomplishes this goal?

Answer. The Moon-Mars mission, as proposed by President Bush, continues many of NASA's successful scientific endeavors including its robotic exploration and research, research in human physiology in a space environment, and the development of newer, more sophisticated nuclear power and propulsion systems. NASA has always supported a broad spectrum of fundamental space-related science activities. That has contributed to the international reputation for high standards of scientific excellence that NASA has garnered throughout its history. Its science programs have not only been the foundation of the agency—its solid underpinning—they have also contributed to its human spaceflight programs by providing knowledge that makes going into space rewarding and the technology that makes human spaceflight possible. In order for NASA to continue to be successful, science should be included among the highest-priority goals of the agency. Otherwise, science falls in the category of "to be protected" rather than "to be enhanced". Science is the heart and soul of NASA. If NASA science is allowed to weaken, then the agency is weakened as well.

Question 4. You discussed the importance of the United States achieving a balance between promoting international collaboration in space exploration and protecting U.S. citizens against terrorist activities.

(a) What do you see as potential threats of international collaboration in space exploration?

Answer. As with every other activity, of course it is important to assure that those who visit our country and with whom we collaborate on space research, developing new technologies, and conducting spaceflight are friends, not enemies, but I would emphasize that scientists have had a long successful history of international collaborations. During WWII, the U.S. brought the best and brightest minds together, regardless of their nationalities, to help develop technology needed to win the war. During the cold war, Russian scientists were invited to visit this country and our scientists visited the Soviet Union. Continuing this openness to people of all nations who wish to come to the U.S. to study and work, has allowed this country to become the technological and economic giant of the world. Promoting a free international exchange between researchers and technical professionals can only improve the work done by NASA and U.S. scientists and engineers. Had we not chosen to involve Russia on the critical path in the construction of the International Space Station, we would not have been able to continue to support the Station following the Columbia tragedy. Many of the brightest and most capable scientists and engineers are born in other countries, obtain their degrees in foreign institutions, even make their discoveries outside our borders. Moreover, the U.S. does not make all the important technological breakthroughs. The cumbersome process used by the State Department to license the export of space technologies has seriously damaged the ability of our space industry (particularly the satellite industry) to compete. This export control process will make cooperation in space very difficult in the future. We harm ourselves by isolating America from this international pool of talent, ideas, and technological capability. Following 9/11, the fear of terrorism is understandable and caution is warranted. However, allowing fear to shut down much of our space industry and cut off interactions between scientists, engineers and other talented individuals will seriously damage our nation—in space and in everything else we believe is important to our future.

(b) How do you think the U.S. can simultaneously guard against these threats while encouraging maximum collaboration with other nations?

Answer. The U.S. can encourage maximal international collaborations by keeping open and honest relationships between researchers and by allowing scientists to interact on a regular basis. NASA and other agencies involved in scientific research can work with the State Department to help streamline the visa process. The U.S. isn't the only nation interested in the exploring the universe and capable of performing the research and developing the necessary technologies. By opening up to ideas from other nations in the pursuit of these goals, we can achieve them faster and cheaper. When we isolate ourselves we become a target, but when we include other nations together we promote a spirit of cooperation and leave terrorists without a message.

Question 5. How will this new mission affect NASA programs not directly related to space exploration, such as Earth Science and Aeronautics enterprises?

Answer. With NASA focusing on space exploration and related research, many of its important astronomy and earth science research will find themselves crippled with cutbacks necessary to fund human space exploration. Already, NASA has announced plans to discontinue servicing the Hubble Space Telescope, which in its 14 years of existence, has expanded our understanding of star birth, star death, and galaxy evolution, and has helped move black holes from theory to fact. Other pro-

grams, such as NASA's Earth Science Enterprise, that provides important data on aspects of the earth's atmosphere, oceans, and land, could also be in jeopardy. These successful programs are vital not only to the future direction of space exploration and research, but programs like the Earth Science Enterprise is key to helping understand climate change and weather prediction two problems we have here on planet Earth. Although I am excited about the implementation of a direction for NASA's human space flight, I'm also concerned that it might harm these and other research project, which are also worthwhile. NASA science must be one of its highest-priority goals. Otherwise it is always in jeopardy of being cut when the budget gets tight. When the President of the United States leaves science out of his new vision, the message is "do the science on the side!" That would be very damaging to NASA and the U.S. space program.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN MCCAIN TO DR. HOWARD E. MCCURDY

Question 1. In your written testimony, you reference the cost overruns for the development and operation of the International Space Station.

(a) Do you see the possibility of similar cost overruns in the new space proposal?

Answer. Without a fundamental change in the way the human space flight program is managed, the cost of the new space endeavor could be astronomical. The Apollo flights to the moon, in today's dollars, cost $150 billion. The moon-Mars initiative is far more ambitious. Yet it need not cost a great deal. Administration officials have set the incremental cost of undertaking the initiative over the next sixteen years at $42 billion (in real year dollars)—the difference between the overall NASA budget with the new initiative and the budget without it. Sixteen years is sufficient time for NASA officials to develop low-cost methods and technologies—or discover that they cannot do so.

The last two human space flight initiatives—the space shuttle and International Space Station—began as cost-reduction efforts. The space shuttle was conceived as a means to cut the cost of space access "by a factor of ten." Yet the people who actually built the space shuttle received so many conflicting objectives that they could securely ignore the cost reduction goal. The people who conceived the original space station deliberately set its price low in an effort to impost cost discipline on NASA field centers and their contractors. In the internal struggle that followed, officials at NASA headquarters lost control of the project to people who ran the program in the traditional, high-cost way. Without substantial changes in the human flight program, that history will occur again.

(b) Do you have any recommendations on how such cost overruns could be avoided in the future?

Answer. NASA executives have achieved substantial cost savings without overruns in their robotic space activities. They have done this by setting firm (and realistic) cost goals and communicating the importance of those goals to project workers. Those workers in turn have elevated the importance of meeting cost targets to a level commensurate with scientific objectives. Workers who fail to meet cost targets have seen their projects terminated. The overall result has been a firm commitment to the technologies and management improvements necessary to complete cost-controlled undertakings.

To repeat this process on the moon-Mars initiative, Congress would need to set firm cost targets for elements within the endeavor, such as the development of the crew exploration vehicle. Congress might also encourage NASA to use an important technique from the robotic science effort. Project advocates are forced to compete to get their projects approved—and there are far more losers than winners. Competition between robotic and human elements might spur innovation in both. It would be a radical move, but Congress might consider combining robotic and human projects at one center. Before President Kennedy launched the moon race, Congress had intended to merge robotic and human flight efforts at what became the Goddard Space Flight Center in Maryland. Together, competition and firm cost targets would give the United States a fighting chance to carry out the new proposal at a reasonable cost.

Question 2. While Administrator O'Keefe has done much to refocus on safety at NASA, it is clear that much remains to be done to change the institutional thinking and culture at NASA in order to continue its current missions, more or less, take on new ones.

(a) Have you seen any significant evidence of this much needed change at NASA?

Answer. Cultural change is a long-term process that requires top-level leadership, new symbols and language, the recruitment of new personnel, extensive training, and fresh programmatic challenges. Administrator O'Keefe recognizes the need for cultural change in the human space flight program and has begun the process. While I have not studied the reforms in sufficient detail to render a specific judgment, I can assure you that cultural change in the human space flight program is unlikely without a fresh programmatic challenge such as that offered by the moon-Mars initiative.

(b) What recommendations would you make regarding such change?

Answer. One of the best reasons for undertaking the moon-Mars initiative is that it promises to transform NASA.

Question 3. In your written testimony, you stated that "NASA has lost too much of its in-house technical capacity." How do you think this loss will impact NASA's ability to produce a successful Moon-Mars mission? What should NASA do to increase its "in-house technical capacity?"

Answer. The history of recent Mars exploration, from Pathfinder (built in-house) to Mars Climate Orbiter (contractor controlled), supports the importance of strong in-house technical capability. Hollow government organizations, without substantial in-house expertise, typically lack the technical authority necessary to restrain cost growth and promote innovation. The best way to enhance NASA's in-house technical capability would be to insist that major systems, such as the crew exploration vehicle, be assembled and tested in-house at NASA facilities. Contractors will continue to make substantial contributions as suppliers of scientific instruments and subsystems, but the assembly and testing process should be done under the direction of small, cohesive, technically-competent NASA teams. The only exception to this rule would be a case in which a contractor received the whole responsibility for a particular mission, as occurred in the development of the Near Earth Asteroid Rendezvous (NEAR) spacecraft, which was build at and flown from the Applied Physics Laboratory in Laurel, Maryland. In general, excessive distribution of work to contractors increases overall costs and creates a hollow NASA that lacks the capacity for smart technical work.

Question 4. What are your thoughts on the American public's lukewarm reaction to the President's proposal?

Answer. Public interest in the Spirit and Opportunity landings was exceptionally high. The Spirit landing was the top news story that week (exceeding public interest in Brittany Spear's wedding which was number two!). Future interest in robotic and human exploration of the inner solar system will be similarly intense, if accompanied by the same technological advances and cost improvements that have characterized robotic flight. Public apprehension arises from the recent history of human space flight and the understandable fear that human elements will cost too much. Informed people rightly suspect that the tradition of cost largess will overwhelm the promise of low-cost innovation.

Question 5. In your written testimony you explain how both the Shuttle and the ISS programs could not meet requirements because they were designed to be all things to all people. How do we prevent missions, such as a lunar outpost or robotic explorers on Mars, from being overburdened with too many requirements and suffering from a lack of focus?

Answer. In the first space exploration initiative (1989), the goal of a lunar base was offered as an objective co-equal to the exploration of Mars. Elaborate lunar facilities, such as the proposal for a lunar construction crane, helped drive cost estimates for the overall program past the $400 billion mark. A similar result might be avoided by keeping the focus on Mars, with the moon serving only as a test bed or proving ground on an as-needed basis.

Question 6. NASA has announced a new Exploration Systems Enterprise. Do you think this is a step in the right direction for transforming NASA to meet its new mission?

Answer. The creation of a strong systems engineering group at NASA headquarters during the 1960s helped the first Americans reach the moon. Space historian Stephen B. Johnson called the Apollo systems engineering group under the leadership of General Samuel C. Phillips the "secret of Apollo." The Exploration Systems Enterprise is an essential first step for the new endeavor. However, it is equally important that NASA improve upon traditional systems management techniques in order to restrain spending. The Apollo systems engineering group coordinated the very large number of subsystems managers and contractors whose presence made the lunar expeditions possible, but those same participants made the overall program extraordinarily complex and expensive. The Exploration Systems Enterprise

for the moon-Mars initiative faces a different challenge—keeping program relationships simple and costs low.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. FRANK R. LAUTENBERG TO DR. HOWARD E. MCCURDY

Question. How much do you believe the President's proposal will ultimately cost the American taxpayers? Is this a realistic estimate?

Answer. I estimate that the president's proposal will cost $42 billion over what the government would otherwise spend on NASA space activities if the proposal was not approved. That covers Fiscal Years 2005 through 2020 and includes adjustments for inflation. (In constant 2005 dollars the sum would be about $36 billion.)

By 2015 or thereabouts, we should know whether we will be able to undertake the next steps in the exploration agenda at a realistic and reasonable cost. I do not think those steps can be accomplished using Apollo-style technology or management. Project Apollo, in today's dollars, cost about $150 billion. Accomplishment of the new vision will require technological and managerial innovations that depart significantly from the practices used during the Apollo years.

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