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THE FUTURE OF NASA: PERSPECTIVES ON STRATEGIC VISION FOR AMERICA'S SPACE PROGRAM

HEARING

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

WEDNESDAY, DECEMBER 12, 2012

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THE FUTURE OF NASA: PERSPECTIVES ON STRATEGIC VISION FOR AMERICA'S SPACE PROGRAM

WEDNESDAY, DECEMBER 12, 2012

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

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

RALPH M. HALL, TEXAS
CHAIRMAN

EDDIE BERNICE JOHNSON, TEXAS
RANKING MEMBER

U.S. HOUSE OF REPRESENTATIVES
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Committee on Science, Space, and Technology

The Future of NASA: Perspectives on Strategic Vision for America's Space Program

Wednesday, December 12, 2012
9:30 a.m.-11:30 a.m.
2318 Rayburn House Office Building

Witnesses

The Honorable Robert Walker, Executive Chairman, Wexler & Walker

Maj. Gen. Ronald Sega, USAF (Ret), Vice Chair, National Research Council Committee on NASA's Strategic Direction

The Honorable Marion C. Blakey, President & CEO, Aerospace Industries Association

Dr. Thomas Zurbuchen Ph.D, Professor for Space Science and Aerospace Engineering, Associate Dean for Entrepreneurial Programs, University of Michigan

Dr. Scott Pace, Ph.D, Director, Space Policy Institute, The George Washington University

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

The Future of NASA: Perspectives on Strategic Vision for America's Space Program

Wednesday, December 12, 2012
9:30 a.m. – 11:30 a.m.
2318 Rayburn House Office Building

Purpose

On Wednesday, December 12, 2012, the Committee on Science, Space, and Technology will hold a hearing titled, "The Future of NASA: Perspectives on Strategic Vision for America's Space Program." The committee will review the National Research Council report on *NASA's Strategic Direction and the Need for a National Consensus*, and hear testimony from witnesses concerning NASA's strategic direction as the Nation faces difficult budgetary challenges.

Over-Arching Questions

- What steps could the government take over the next 3 to 5 years to help maintain America's capabilities and retain world leadership in space?
- What are the priorities that policy makers should consider when evaluating future NASA plans?
- How best can NASA and its stakeholder community reach consensus on identifying and preserving critical capabilities necessary for future space science, aeronautics, and exploration programs and missions?
- What steps can NASA, Congress, and the White House take to promote greater overall efficiency at the agency, as well as maintain programmatic and funding stability for projects and programs?

Witnesses

The Honorable Robert Walker, Executive Chairman, Wexler & Walker

Maj. Gen. Ronald Sega, USAF (Ret), Vice Chair, National Research Council Committee on NASA's Strategic Direction

The Honorable Marion C. Blakey, President & CEO, Aerospace Industries Association

Dr. Thomas Zurbuchen Ph.D, Associate Professor for Space Science and Aerospace Engineering, Associate Dean for Entrepreneurial Programs, University of Michigan

Dr. Scott Pace, Ph.D, Director, Space Policy Institute, The George Washington University

NASA Budget

NASA's budget has been relatively flat over the 15-year period from 1997 to 2011. During this period the budget each year has varied by no more than 5 percent from the average value of $18.4 billion (in FY2011 dollars).[1] NASA received $17.77 billion (actual) in FY2012; the Administration's FY2013 NASA budget request is $17.71 billion and the 4 year budget run out calls for flat funding at the same level.

Figure 1 illustrates the Administration's budget requests from FY2010 through FY2013 compared to the actual amounts appropriated by Congress.

	2009	2010	2011	2012	2013	2014	2015	2016	2017
FY10 Request		$18.69	$18.63	$18.61	$18.60	$18.86			
FY11 Request			$19.00	$19.45	$19.96	$20.60	$20.99		
FY12 Request				$18.72	$18.72	$18.72	$18.72	$18.72	
FY13 Request					$17.71	$17.71	$17.71	$17.71	$17.71
Actual	**$18.78**	**$18.72**	**$18.45**	**$17.77**					

Figure 1(Amounts shown in billions of dollars)[2]

While overall funding for NASA has been flat over the last 15 years, *projected* budget increases have varied greatly from year to year. As a result, planning for large, multi-year procurements has been difficult and inefficient. In certain programs, such as human spaceflight, there has been a recurring cycle in which the projected budget increases necessary to develop complex systems have not materialized. The subsequent flat budgets have contributed to increased costs and schedule delays of new systems.

Figure 2 illustrates the percentage of NASA's budget currently devoted to each major activity. NASA's science directorate (28.6%) includes planetary science, Earth science, heliophysics, astrophysics, and the James Webb space telescope. Exploration (21.2%) is developing the space launch system and Orion crew vehicle for human exploration beyond low Earth orbit, as well as the commercial crew program to support the International Space Station. Space Operations (23.8%) is primarily associated with the International Space Station. Aeronautics represents approximately 3 percent of the budget, and the remaining budget funds cross-agency support (16.8%), space technology (3.2%), construction of facilities (2.2%), education (0.8%), and the office of the inspector general (0.2%).

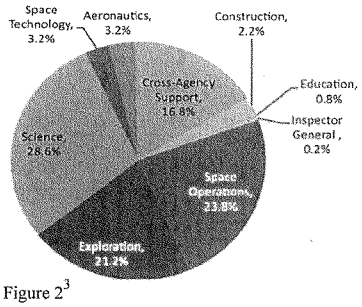

Figure 2[3]

[1] NASA's Strategic Direction and the Need for a National Consensus, NRC, Dec. 2012
[2] FY10 – FY12 Budget Estimates, NASA/OMB

Science

NASA's Science budget has been relatively stable for the last several years at $4.5 billion in FY2010, $4.9 billion in FY2011, $5.0 billion in FY2012, and $4.9 billion in FY2013. The most notable recent changes are within the planetary science budget, which went from $1.5 billion in FY2012 to a requested $1.2 billion for FY2013 – a net decrease of over 20%.

Despite relatively flat funding for the science directorate overall, factors such as cost overruns and the lack of small and medium-sized launch vehicles resulting in the need to use larger, more expensive vehicles are eating away at the funds available to do actual science missions.

As a result, the President's FY2013 budget request indefinitely puts on hold NASA's flagship missions – with no new starts as recommended in decadal surveys published by the National Research Council for major missions to Mars[4] (Mars Sample Return), the outer planets (Europa or Uranus) or for the next astrophysics mission (Wide Field Infrared Survey Telescope or WFIRST). It is widely held that NASA's flagship missions, while expensive, are the only means by which certain scientific problems can be effectively addressed. With unmatched complexity and scope, flagship missions set NASA apart from other space agencies around the world. These missions also rely on a vibrant pipeline of scientists and engineers that might otherwise not be available in the future should no new missions begin.

Exploration

NASA's Exploration budget has undergone severe changes in the last several years. In FY2010 NASA's Exploration budget was $3.8 billion and was slated to increase to $6.0 billion by FY2013 to build the *Constellation* system which had received broad bipartisan support for several years. The following year (FY2011) the Administration abruptly canceled the program without warning either Congress or the broader international space community, which had been shifting its attention and funding toward contributing to a U.S.-led lunar mission. The cancelation of *Constellation* and abandonment of a lunar mission caused uncertainty throughout the international community. The lack of clear consensus on the direction has made it difficult to justify future funding for anything beyond the International Space Station.

For these and other reasons Congress did not concur with the Administration's proposal to eliminate development of systems for beyond Earth orbit, and directed NASA to continue work on designing and building a heavy lift Space Launch System and Orion crew capsule in the NASA Authorization Act of 2010.

The Exploration account also provides funding for the commercial crew program that is designed to provide crew transportation services to the International Space Station. The 2010 NASA Authorization Act (PL 111-267) authorized $500 million for FY2013 for this activity, yet NASA is seeking $825 million, arguing that commercial operations would not be possible by 2017 without this level of effort. Thus, development of "commercial" systems competes against the heavy-lift launch system for funding within the Exploration Systems budget.

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[3] NASA's Strategic Direction and the Need for a National Consensus, NRC, Dec. 2012

[4] On Dec. 4, NASA announced its intention to initiate a new Mars lander mission that will be similar to the Mars Curiosity rover. A formal funding request is expected in the FY2014 budget request due next spring.

Aeronautical Research

Current civil, general aviation, and military aircraft contain many technologies developed by NASA including, fly-by-wire, flight management systems, quieter fuel efficient turbine engines, and incorporation of composite materials into airframes and structures are just a few examples. Manufacturers world-wide have adopted NASA-developed technologies into their products.

Over the last decade, the budget for Aeronautics has been reduced from a peak of approximately $1 billion ten years ago to just $569.9 million in FY2012. The President's FY2013 budget request is slightly lower at $551.5 million and remains flat in the budget run-out. As a share of NASA's budget, the percentage allocated to research in Aeronautics has dropped from approximately 7 percent in 2000 to approximately 3 percent in 2012. Currently, for every dollar the agency spends on aeronautics, it spends $23 on space-related activities.[5]

Background of the National Research Council Study

Concerned that NASA's budget will be significantly constrained as a result of continuing fiscal pressures, Congress directed the NASA Office of the Inspector General (P.L.112-55) to commission a comprehensive independent assessment by the National Research Council (NRC) of NASA's strategic direction.[6]

Per the House report:

> *Comprehensive independent assessment.—NASA has a broad mandate to execute a balanced space program that includes science, technology development, aeronautics research, human spaceflight and education. NASA regularly receives management and programmatic recommendations from GAO, the Office of Inspector General (OIG) and various commissions and other entities, as well as outside advice on scientific and technical priorities from the National Academies.*
>
> *While each of these reviews is useful on its own, they are generally targeted to a specific issue or program and therefore do not provide a comprehensive assessment of NASA's activities. The conferees believe that such an agency-wide assessment will provide a means to evaluate whether NASA's overall strategic direction remains viable and whether agency management is optimized to support that direction.*

As part of the overall assessment, the NRC evaluated NASA's 2011 Strategic Plan which, "*outlines our long-term goals as an agency and describes how we will accomplish these goals over the next decade or more.*"[7]

[5] NASA's Strategic Direction and the Need for a National Consensus, NRC, Dec. 2012
[6] P.L. 112-55, House Report 112-284
[7] 2011 Strategic Plan, Message From the Administrator, Feb. 4, 2011

NASA 2011 Strategic Plan Goals[8]

- Extend and sustain human activities across the solar system.
- Expand scientific understanding of the Earth and the universe in which we live.
- Create the innovative new space technologies for our exploration, science, and economic future.
- Advance aeronautics research for societal benefit.
- Enable program and institutional capabilities to conduct NASA's aeronautics and space activities.
- Share NASA with the public, educators, and students to provide opportunities to participate in our Mission, foster innovation, and contribute to a strong national economy.

The National Research Council Report

The National Research Council (NRC) Committee on NASA's Strategic Direction was tasked to address the evolution of NASA's goals, objectives, and strategies, including in particular those set forth in the *2011 NASA Strategic Plan.* The committee's statement of task can be found in Appendix 1.

The committee considered the full range of NASA's activities, including space and Earth science; aeronautics; advanced technology development; human space exploration; spaceflight operations; and STEM education. On December 5, 2012, the NRC released its final report entitled, *NASA's Strategic Direction and the Need for a National Consensus.*

According to the NRC's report, the 2011 strategic plan presents a vision and mission that is vague and generic, one that is not unique to the nation's space and aeronautics enterprise, and that could apply to almost any government research and development agency. In fact, the NRC rendered the 2011 Strategic Plan "of little value," particularly given the fiscal challenges our country is facing. According to the committee, current budget trends "requires much clearer justification and prioritization for the plan to be meaningful."[9]

To be of real utility to the nation, the committee recommends a long-term NASA strategy that provides benefit to the nation, is integrated across mission areas, provides opportunity for scientific and engineering excellence and innovation, is credible, is global in perspective and provides for interagency collaboration.[10]

Among the findings, the NRC found that budget instability and limitations (both legislative and regulatory) have hampered NASA's flexibility to manage the agency in the most efficient way, which has translated into a mismatch of budgets and missions.

[8] 2011 Strategic Plan
[9] NASA's Strategic Direction and the Need for a National Consensus, NRC, Dec. 2012 , p. 31-32
[10] Ibid., pg. 39-40

The report cites examples within each major research area. For exploration, the committee found "little evidence" that the human asteroid mission by 2025 has been accepted as a compelling destination by NASA workers, the nation or by the international community. In science, the current decadal survey process has been deemed successful but without a sustainable budget. Many key priorities will likely not be pursued within any meaningful timeframe. According to the report, the decline in the aeronautics program seems to be without a clear rationale. Finally, the newly developed technology program shows promise with a clear road-map, but has yet to be funded at the requested levels.[11]

The NRC report outlines four approaches that policy makers could pursue to re-align NASA's mission with its budget.

> *Option 1:* Institute an aggressive restructuring program to reduce infrastructure and personnel costs to improve efficiency.
>
> *Option 2:* Engage in and commit for the long term to more cost-sharing partnerships with other U.S. government agencies, private sector industries, and international partners.
>
> *Option 3:* Increase the size of the NASA budget.
>
> *Option 4:* Reduce considerably the size and scope of elements of NASA's current program portfolio to better fit the current and anticipated budget profile. This would require reducing or eliminating one or more of NASA's current portfolio elements (human exploration, Earth and space science, aeronautics, and space technology) in favor of the remaining elements.

These options, described in detail within the report, illustrate tradeoffs that need to be considered when charting a path forward for NASA.

[11] NASA's Strategic Direction and the Need for a National Consensus, NRC, Dec. 2012

APPENDIX 1

NRC Statement of Task

The National Research Council will appoint an ad-hoc committee to assess whether the strategic direction of the National Aeronautics and Space Administration, as defined by the 2011 NASA strategic plan, remains viable and whether the agency's activities and organization efficiently and effectively support that direction in light of the potential for constrained budgets for the foreseeable future. In particular the committee will:

1. Consider the strategic direction of the agency as set forth most recently in 2011 NASA Strategic Plan and other relevant statements of space policy issued by the President of the United States.

2. Consider the goals for the agency set forth in the National Aeronautics and Space Act of 1958 (as amended) and the National Aeronautics and Space Administration Authorization Acts of 2005, 2008 and 2010.

3. Consider previous studies and reports relevant to this task.

4. Assess the relevance of NASA's strategic direction and goals to achieving national priorities.

5. Assess the viability of NASA's strategic direction and goals in the context of current budget expectations and stated programmatic priorities for the agency.

6. Discuss the appropriateness of the budgetary balance between NASA's various programs;

7. Examine NASA's organizational structure and identify changes that could improve the efficiency and effectiveness of the Agency's mission activities; and

8. Recommend how NASA could establish and effectively communicate a common, unifying vision for NASA's strategic direction that encompasses NASA's varied missions.

Chairman HALL. Okay. Good morning to everyone. The Committee on Science, Space, and Technology will come to order. Welcome to today's hearing entitled "The Future of NASA: Perspectives on Strategic Vision for America's Space Program" is our topic for today, and in front of you are packets containing the written testimony, biographies and the Truth in Testimony disclosures for today's witnesses.

Before I get into my opening statement, I want to say a few words about some folks on this Committee. I don't believe hardly any of them are here, and maybe we ought to wait until they show, but I want to talk about Roscoe Bartlett and Judy Biggert, Todd Akin, Sandy Adams, Ben Quayle, Chip Cravaack; on the Democratic side, Jerry Costello, about as kind and classy guy as you will ever know is not coming back to use, and Hanson Clarke of Michigan. Of course, Lynn Woolsey, she is usually here to fuss at me. I proposed to her three times and she turned me down four. But they will be here in a little bit.

In the meantime, let me recognize the next Chairman of this Committee, a long, long-term friend of mine, a person I absolutely couldn't do without, wouldn't want to be in Congress if he were not in Congress with me, my friend from San Antonio who will be chairing this Committee for probably the next ten years, and I am going to be right with him. We hope we can do some things to EPA. We hope we can work on a health bill. We hope we can do a lot of things together. Mr. Chairman, I am honored to have you.

I guess I can go on and just read for the record. What do you think I ought to do, Eddie? Wait until they get here? I will go on with my opening statement.

Ms. JOHNSON. We have an organization meeting, so they probably will not be coming.

Chairman HALL. Okay.

Ms. JOHNSON. A caucus organization, a committee.

Chairman HALL. This is the first opening statement I have had that is 1,020 pages. I read well from a printed page. It is not going to take me very long, and they are beginning to show, so I recognize myself for five minutes or so for an opening statement.

And I say once again good morning, and welcome to today's hearing. I want to especially recognize some of our colleagues, and our colleague and friend, Robert Walker, the former Chairman of this Committee for many years, for agreeing to testify here today. Bob, it is good to see you and I thank you and the other witnesses for being with us. I recognize that it takes a lot of time and effort goes into the preparation of hearing testimony. I want you all to know that your expert knowledge and your vast experience is very useful to the Committee. Without you, we could not have a bill nor have a recommendation for the future. As we consider legislation, we also thank you for taking the time to appear here today.

There are a number of significant issues confronting NASA and its space program: a diminishing number of missions under development in the space sciences area; an aeronautics budget that can no longer support full-scale demonstration flights; and no clearly articulated vision for our human exploration program beyond the International Space Station. And that International Space Station to me is the number one. We have got to get there first and have

some security there before we can even think about the other. We can think about it and may have some plans for it, but with regard to human space flight, during the national debate following the Columbia accident nearly ten years ago, we emerged with guiding principles and goals that were overwhelmingly endorsed by both Republicans and Democrats in the House and Senate, resulting in the NASA Authorization Acts of 2005 and 2008. Even though funding was often less than many of us recommended, there was a consensus on the overall strategic direction. That consensus was short-lived when the Administration, with no notice, abruptly canceled Constellation via submission of the fiscal year 2011 budget. The current agreement, if it can be called that, is not a consensus as much as it is a compromise. No one got everything they wanted, but the lack of a clear consensus grounded in an agreement on national priorities resulted in no effective way to prioritize the many competing demands. It has been clear over the last few budget cycles that there are fundamental disagreements. Constellation was an integrated development plan to first replace the space shuttle's access to the space station in low-Earth orbit and then evolve over there into heavy-lift rockets allowing NASA take longer strides and once again reach beyond low Earth to the Moon and then on beyond.

At Congress's insistence the present compromise includes a heavy-lift rocket development program, but the general lack of consensus on goals and destination has sown the seeds for disappointment as three large development programs, the Space Launch System, the Orion crew capsule and the Commercial Crew program compete for the same diminishing resources in NASA's Exploration Systems budget. Since the Commercial Crew program supports the ISS, perhaps it should more appropriately be funded by the Space Operations budget. The Administration, Congress and NASA should all look for ways to eliminate waste and duplication.

We are in a very challenging budget environment, and that will be with us for some time, for the next several years. Fiscal realities demand that NASA become more efficient and sized correctly to accomplish its goals, but consensus will have to be reestablished among the agency's stakeholders to comply and also to clarify NASA's strategic vision, their goals and their missions.

The good work that NASA has done, and that NASA can do in the future, is so very important to me and to us, to everyone here in this room. I want to preserve our International Space Station, and as a strategic goal to go beyond it. But it is not likely with this Congress and this electorate that we can expect vast sums for the moon, Mars, or an asteroid. We can't go to Mars until our people can go to the grocery store. In other words, it is about the economy. The economy has to improve before NASA funding increases. I want us to work together to ensure that the American people get the kind of results that NASA is capable of producing and has demonstrated so often. We have a very distinguished panel of witnesses today and I look forward to this hearing and should really spark a much-needed national dialogue about NASA's future. This group is uniquely qualified to start this very important discussion by sharing their own perspectives about the strategic direction of America's space program.

That concludes my remarks.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF CHAIRMAN RALPH HALL

Good morning, and welcome to today's hearing. I want to especially recognize our colleague and friend, The Honorable Robert Walker, the former Chairman of this Committee, for agreeing to testify here today. Bob it's good to see you. But I thank all our witnesses for being with us. I recognize that a lot of time and effort goes into the preparation of hearing testimony. I want you all to know that your expert knowledge and vast experience is very useful to this Committee and Congress as we consider legislation, so thank you for taking the time to appear here today.

There are a number of significant issues confronting NASA and its space program: a diminishing number of missions under development in the space sciences arena; an aeronautics budget that can no longer support full-scale demonstration flights; and no clearly articulated vision for our human exploration program beyond the International Space Station.

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Chairman HALL. I now recognize Mrs. Johnson for her opening statement.

Ms. JOHNSON. Thank you very much, Mr. Chairman, and good morning to all. I want to particularly welcome our witnesses, and a former Chair that I previously served with, and I look forward to all of the testimony. At this time the Democratic Caucus is having a meeting, an organizational meeting that started—it was supposed to start at nine but because of the lateness of the ranking

member meeting, it started a little bit late—so our Members that are returning and concerned about what committees they are going to be on for the next time will probably not be here today.

Today's hearing is an important one for the Committee, because NASA is a critical part of the Nation's research and development enterprise, as well as being a source of inspiration for our young people and a worldwide symbol of American technological prowess, leadership and goodwill. We want NASA to succeed in its endeavors, because its success benefits our Nation in many, many ways.

In establishing NASA through the Space Act of 1958, Congress directed the agency to contribute materially to the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere. Successive NASA Authorization Acts over the years have stressed the need for a balanced program of science, aeronautics, technological research, and human spaceflight and exploration. The result has been that this balanced program has given advances that have enhanced knowledge, promoted innovation and economic vitality, inspired our youth, and deepened our understanding of the Earth and environment.

However, in recent years NASA's ability to carry out its missions has been eroded. In that regard, it is estimated that NASA's purchasing power has actually decreased by about 18 percent in constant dollars from fiscal year 1992 to fiscal year 2012 in spite of the agency being given a number of major initiatives to carry out over that same period. In fact, last year's appropriated budget was about $1 billion less than in fiscal year 2010. The cumulative impact of this budgetary instability has been felt by all of NASA's programs and its institutional infrastructure, a problem also highlighted by NASA's Inspector General in a recent report. And we will hear similar concerns raised by the National Research Council witness today, as he discusses his panel's recently released report.

Ironically, the issues considered by the NRC panel are not new to this Committee. We have heard them raised in one form or another in both this and previous Congresses. I hope that the findings of the NRC panel's assessment will encourage both the Administration and Congress to put NASA on a firmer footing and to recognize NASA for the national asset that it is.

While NASA's programs are funded as part of the federal domestic discretionary budget, we should not forget that those programs are long-term R&D undertakings, and they can't just be turned on and off whenever we have a short-term fiscal issue needing attention, not if we want them to be successful and not if we want to maintain our commitment to the dedicated workforce that is trying to bring them to fruition. That is a challenge we are going to face in the coming months and years as we work to put the Nation's financial house in order. Because we forget at our peril the hard reality that investments in R&D and innovation, such as in the programs and projects carried out at NASA are just that—investments—investments in our Nation's future and in the future of our children.

It may only be in retrospect that we will learn the true costs of walking away from investments in R&D agencies such as NASA,

but I firmly believe that those costs will be high and long-lasting if we go down such a destructive path. I hope we don't do so, because other nations increasingly recognize the benefits that a strong and active space program can deliver, and as a result we see them being willing to make the necessary investments to build their capabilities, even in the days of austerity.

Mr. Chairman, our leadership and preeminence in space and aeronautics are at stake. Our children's future jobs and long-term global competitiveness are at stake. Resting on our laurels from prior accomplishments is not an option, whether in science, aeronautics, or human exploration. That is not to say that we shouldn't do all we can to encourage efficiencies in NASA's programs and infrastructure and eliminate waste wherever we find it. But all of those efficiencies will be for naught if we do not also recognize that sustained investments in research, technology and development must also be made if NASA is to succeed.

Mr. Chairman, before I conclude my remarks, allow me to take a moment to thank Mr. Costello, Ms. Woolsey, Mr. Miller, and Mr. Clarke for their service to our Nation. Each of them will be departing the House of Representatives at the completion of the 112th Congress, and I want to wish them well. They have been thoughtful and hardworking Members of our Committee caucus, and I shall miss them.

And with that, I yield back the balance of my time.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF RANKING MEMBER EDDIE BERNICE JOHNSON

Good morning. I want to join Chairman Hall in welcoming our witnesses. And in particular, I want to welcome former Chairman Walker back to the Committee. I look forward to each of your testimonies.

Today's hearing is an important one for the Committee, because NASA is a critical part of the Nation's research and development enterprise, as well as being a source of inspiration for our young people and a worldwide symbol of American technological prowess, leadership, and good will. We want NASA to succeed in its endeavors, because its success benefits our nation in so many ways.

In establishing NASA through the Space Act of 1958, Congress directed the agency to "contribute materially" to "The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere."

Successive NASA Authorization Acts over the years have stressed the need for a balanced program of science, aeronautics, technological research, and human space flight and exploration. The result has been that this balanced program has driven advances that have enhanced knowledge, promoted innovation and economic vitality, inspired our youth, and deepened our understanding of the Earth and its environment.

However, in recent years NASA's ability to carry out its missions has been eroded. In that regard, it's estimated that NASA's purchasing power has actually decreased by about 18 % in constant dollars from FY 1992 to FY 2012 in spite of the agency being given a number of major initiatives to carry out over that same period. In fact, last year's appropriated budget was about $1 billion less than in FY 2010. The cumulative impact of this budgetary instability has been felt by all of NASA's programs and its institutional infrastructure, a problem also highlighted by NASA's Inspector General in a recent report. And we will hear similar concerns raised by the National Research Council witness today, as he discusses his panel's recently released report.

Ironically, the issues considered by the NRC panel are not new to the Committee. We have heard them raised in one form or another in both this and previous Congresses. I hope that the findings of the NRC panel's assessment will encourage both the Administration and Congress to put NASA on a firmer footing and to recognize NASA for the national asset that it is.

While NASA's programs are funded as part of the Federal domestic discretionary budget, we should not forget that those programs are long-term R&D undertakings, and they can't just be turned on and off whenever we have a short-term fiscal issue needing attention-not if we want them to be successful, and not if we want to maintain our commitment to the dedicated workforce that is trying to bring them to fruition. That is a challenge we are going to face in the coming months and years as we work to put the nation's financial house in order. Because we forget at our peril the hard reality that investments in R&D and innovation, such as in the programs and projects carried out at NASA are just that—investments—investments in our nation's future and in the future of our children.

It may only be in retrospect that we will learn the true costs of walking away from investments in R&D agencies such as NASA-but I firmly believe that those costs will be high and long-lasting if we go down such a destructive path. I hope we don't do so, because other nations increasingly recognize the benefits that a strong and active space program can deliver, and as a result we see them being willing to make the necessary investments to build their capabilities.

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Mr. Chairman, before I conclude my remarks, allow me to take a moment to thank Mr. Costello, Ms. Woolsey, Mr. Miller, and Mr. Clarke for their service to our nation. Each of them will be departing the House of Representatives at the completion of the 112th Congress, and I want to wish them well. They have been thoughtful and hardworking Members of our Committee caucus, and I shall miss them.

Chairman HALL. The gentlelady yields back.

If there are other Members who wish to submit additional opening statements, your statements will be added to the record at this point.

Chairman HALL. We have some of our departing Members here, and I think it is time to say a few words about them before I start my opening statement and before we introduce the witnesses properly. I would like to say a few words about several Members of our Committee and thank them for their dedication to the Congress and to the Science, Space, and Technology Committee. On the Republican side, Roscoe Bartlett—I don't know if Roscoe is here or not, but Roscoe, I always enjoy telling him he is too old to be here. His questions give me more information than the answers he elicits, but he is a great Member, and I am both surprised and disappointed that he was defeated, and I am proud and pray for whoever is going to take his place, if they yield the service that that old fellow yielded.

And then of course, Judy Biggert, we all know had her national lab in Argonne, and an outstanding Member. We were conferees on the National Defense Act. I found Judy on the right side of everything, and we are really, really going to miss her.

Todd Akin of Missouri had a strong showing for the Senate and had some rocks and handicaps along the way but he is a good man. He served well for us, and people kept writing to me telling me to put him off this Committee, and I said time and time again, if I could put anybody off the Committee, I would put Sensenbrenner off or Eddie Bernice or somebody, but we don't have the right to put anybody off, and we couldn't do without Sensenbrenner. He is still here.

Mr. SENSENBRENNER. Yes.

Chairman HALL. And doing a good job.

Sandy Adams of Florida is still young enough to continue her fight for NASA and for the Kennedy Space Center. She did a good job of that.

Ben Quayle, young man, he is not here either today but I knew his father so well. I spent 7 or 8 days in Russia with his dad, and I was with him when he made a speech to the retiring editors and the retiring school people there, all of them Communist, and he was making his speech and he made the mistake of opening it up for questions, and the way Russians ask questions, they make about a 15-minute speech and then get into their question, but after their speech they said if you love us so much, why do you still have all those guns pointed toward us, and Dan and I were way back down away from them, there was a rail between us, and they couldn't hear what I said to him. I said "Tell the SOB you don't trust him," and Dan said if I ever did him like that again, he would get up and walk out of there because he said he would laugh and they would run both of us out there. But he made a good speech back to them and told them they had a place at the table and he believed that one day they would be there. His son is a very fine young man, did a wonderful job as vice chairman of this Committee, and we will miss that young man.

How do you lose a guy like Chip Cravaack? A Navy fighter pilot—I don't hold that against him—for many years as an airline pilot, very knowledgeable, fought for everything that was right. He served with me on a—I believe we served together on the Transportation Committee.

Jerry Costello, there is no more classy guy anywhere than Jerry. He is going back to Illinois. We are going to really miss him, miss his work here and miss his friendship.

Lynn Woolsey—is Lynn here yet? She is not here.

Brad Miller of North Carolina—Brad and I have gone at it several times. I have learned something from him, several things. He is a class guy. He goes back to one of the better law practices in North Carolina. All my folks coming from Cannon Mills, Kannapolis, not very far, Brad, from where you live. You are young enough to come back, and I wish you well and we will miss you on this Committee. You have been a great Member.

And Hanson Clarke. We did a launch together and he was a great guy.

It is an honor to serve on this Committee with all of you. Your dedication, experience and wisdom is going to be deeply missed by this Congress and the next Congress, but no matter what they go to next, they will always be friends and colleagues, and I look forward to seeing them back. Maybe we will ask them to testify like we have asked Bob Walker here to testify today. And Ms. Johnson, again, I thank you for yielding back.

At this time I would like to introduce our panel of witnesses. The Hon. Robert S. Walker needs little introduction in this room. As the former Chairman of this Committee, Bob led this Committee from 1995 to 1997, and since retiring from Congress after 20 years of elected office, he is now the Executive Chairman of Wexler & Walker Public Policy Associates.

Our next witness is retired Major General Ronald Sega. General Sega is here today in his capacity as the Co-Chair of the National Research Council Committee on NASA's Strategic Direction. General Sega currently serves as Vice President and Enterprise Executive for Energy and the Environment for Colorado State University and Ohio State University. He led a very distinguished career in the U.S. Air Force and at NASA, mostly recently as Under Secretary of the Air Force, DOD Executive for Space, and prior to that, as Director of Defense Research and Technology. As an astronaut, General Sega flew two space shuttles, STS–60 in 1994 and STS–76 in 1996, and General, we certainly welcome you.

We next welcome the Hon. Marion Blakey, who is the President and CEO of Aerospace Industries Association representing more than 150 leading aerospace manufacturers. Prior to AIA, Mrs. Blakey served a five-year term as Administrator of the FAA, and before that, as Chairman of the National Transportation Safety Board. Mrs. Blakey, we do really welcome you.

And our next witness is Dr. Thomas Zurbuchen, Associate Professor for Space Science and Aerospace Engineering at the University of Michigan. He is a specialist in robotic exploration in space and team leader for the development of the Fast Imaging Plasma Spectrometer on the Messenger spacecraft in orbit around the planet Mercury, and we certainly welcome you.

And our next witness, Dr. Scott Pace, is the Director of the Space Policy Institute and a Professor in the practice of international affairs at George Washington's Elliott School of International Affairs. From 2005 to 2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA. Prior to that, he was Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy. Dr. Pace, we welcome you as well.

And as our witnesses should know, testimony is limited to five minutes, after which the Members of the Committee will have five minutes each to ask questions, and you are not just held to five minutes. Your time is valuable. You took your time to prepare to come here. It took you years to get prepared to be asked to come here, and you are here, and your time is very, very important. We won't hold you to the five minutes. Just do your best. Our Committee protocol dictates that we recognize the former Science Chairman, Bob Walker, as our first witness, but we have talked and discussed, and I know from reading the testimony that he refers to many of the details in the NRC report. With his indulgence and with our discussion, at his suggestion, I think it would be useful to hear General Sega describe the NRC's findings, and then turn to Chairman Walker and the other witnesses for their testimony. Do I hear an objection? The Chair hears none.

General Sega, the Committee now recognizes you for five minutes to present your testimony.

STATEMENT OF MAJ. GEN. RONALD SEGA, USAF (RET), VICE CHAIR, NATIONAL RESEARCH COUNCIL COMMITTEE ON NASA'S STRATEGIC DIRECTION

General SEGA. Mr. Chairman, Ranking Member Johnson, Members of the Committee, colleagues, I am Ron Sega, Vice Chair of the

National Research Council's Committee on NASA's Strategic Direction. On behalf of Al Carnesale, chair of the committee, and our 12 members, it is my pleasure to come before you today to speak to you about the work of our committee.

Our committee was charged with considering the strategic direction of the agency as set forth most recently in the 2011 NASA Strategic Plan and other relevant statements of space policy issued by the President of the United States.

We were also charged with considering the goals of the agency as set forth in the 1958 National Aeronautics and Space Act as well as recent legislation, and with assessing the relevance of NASA's goals and national priorities.

Finally, we were charged with recommending how NASA could establish and effectively communicate a common, unifying vision for NASA's strategic direction that encompasses NASA's varied missions. Our committee was not charged with establishing strategic goals for NASA, and we did not do so.

Our committee consists of members from industry and academia, former NASA aerospace officials and former analysts and experts from both the executive and legislative branches.

We met five times throughout 2012. The committee received input from nearly 800 members of the public through a web-based questionnaire, and small groups of Committee Members visited each of the nine NASA field centers and the Jet Propulsion Laboratory. The resulting report entitled: "NASA's Strategic Direction and the Need for a National Consensus" is a consensus report by the committee.

As I am sure you are aware, NASA has been tugged in multiple directions for the past several years. Despite a turbulent policy environment, the agency has made many astonishing accomplishments. There remains, however, a lack of consensus on the agency's future direction among the United States political leadership. Without such a consensus, the agency cannot be expected to develop or work effectively toward long-term priorities. In addition, there is a mismatch between the portfolio of programs assigned to the agency and the budget allocated by Congress. What we found during the course of our deliberations was rather obvious: although NASA develops a strategic plan on a regular basis, the agency itself does not establish its strategic goals. Those are developed by the national leadership, and key stakeholders within the national leadership do not always agree on the goals the agency should pursue.

Thus, our committee recommends that the Administration should take the lead in forging a new national consensus on NASA's future that is stated in terms of a set of clearly defined strategic goals and objectives. This process should apply both within the Administration and between the Administration and Congress and should be reached only after meaningful technical consultations with the private sector and potential international partners.

The strategic goals and objectives should be ambitious yet technically rational and should focus on the long term. Following the establishment of a new consensus on the agency's future, NASA should establish a new strategic plan that provides a framework for decisions on how the agency will pursue its strategic goals and ob-

jectives, allows for flexible and realistic implementation, clearly establishes agency-wide priorities to guide the allocation of resources within the agency budget, and presents a comprehensive picture that integrates the various fields of aeronautics and space activities.

To reduce the mismatch between the agency's activities and the resources allocated to it, the White House, Congress and NASA, as appropriate, could employ any or all of the following four non-mutually exclusive options. The committee does not recommend any one option or combination of options, but presents these to illustrate the scope of decisions and trades that could be made.

Option 1: Institute an aggressive restructuring program to reduce infrastructure and personnel costs to improve efficiency. Option 2: Engage in and commit for the long term to more cost-sharing partnerships with other government agencies, private sector industries and international partners. Option 3: Increase the size of the NASA budget. Option 4: Reduce considerably the size and scope of elements of NASA's current program portfolio to better fit the current and anticipated budget profile. This would require reducing or eliminating one or more of NASA's current portfolio elements—human exploration, Earth and space science, aeronautics and space technology—in favor of the remaining elements. Each of these sample options, with the possible exception of option 2, would require legislative action.

Our recommendation with respect to NASA centers states first: The Administration and Congress should adopt regulatory and legislative reforms that would enable NASA to improve the flexibility of the management of its centers. Second, NASA should transform its network of field centers into an integrated system that supports its strategic plan and communications strategy and advances its strategic goals and objectives.

With regard to partnerships, the committee recommends NASA should work with other government agencies with responsibilities in aeronautics and space to more effectively and efficiently coordinate the Nation's aeronautics and space activities, and the United States should explore opportunities to lead a more international approach to future large space efforts, both in the human space program and in the science program.

The committee was impressed with the quality of personnel and the level of commitment of NASA's civil service and contractor staffs and with the superb work done by the agency in general. However, the committee also heard about the frustration of many staff with the agency's current path and the limitations imposed upon it by the inability of the national leadership to agree upon a long-term direction for the agency. Only with a national consensus on the agency's future strategic direction, along the lines described in this report, can NASA continue to deliver the wonder, the knowledge, the national security and economic benefits, and the technology that typified its history.

Thank you for the opportunity to testify. I would be pleased to respond to any questions the Committee might have.

[The prepared statement of General Sega follows:]

Written Testimony of

Ronald M. Sega
Colorado State University and The Ohio State University
and
Vice Chair, Committee on NASA's Strategic Direction
Division Committee on Engineering and Physical Sciences
National Research Council
The National Academies

before the

Committee on Science, Space, and Technology
U.S. House of Representatives

December 12, 2012

Mr. Chairman, Ranking Member Johnson, members of the committee, colleagues: I am Ron Sega, Vice Chair of the National Research Council's Committee on NASA's Strategic Direction. On behalf of Albert Carnesale, chair of this committee and our 12 members, it is my pleasure to come before you today to speak to you about the work of our committee. The National Research Council (NRC) is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology. In late 2011, the United States Congress directed the NASA Office of the Inspector General to commission a "comprehensive independent assessment of NASA's strategic direction and agency management." Subsequently, NASA requested that the NRC conduct this independent assessment. In the spring of 2012, the NRC Committee on NASA's Strategic Direction was formed and began work on its task. (The full Statement of Task appears at the end of this written testimony.) I am here to report on the results of that study.

Our committee was charged with considering "the strategic direction of the agency as set forth most recently in 2011 NASA Strategic Plan and other relevant statements of space policy issued by the President of the United States." We were also charged with considering the goals of the agency as set forth in the 1958 National Aeronautics and Space Act as well as recent legislation, and with assessing the relevance of NASA's goals to national priorities. Finally, we were charged with recommending "how NASA could establish and effectively communicate a common, unifying vision for NASA's strategic direction that encompasses NASA's varied missions." Our committee was not charged with establishing strategic goals for NASA, and we did not do so.

Our committee consisted of members from industry and academia, former NASA aerospace officials, and former analysts and experts from both the executive and legislative branches. We met five times throughout 2012. The committee received input from nearly 800 members of the public through a web-based questionnaire, and small groups of committee members visited each of the nine NASA field centers and the Jet Propulsion Laboratory (JPL). Furthermore, the committee considered a large number of studies conducted by the NRC and other groups over the decades that made recommendations about the conduct of NASA's programs and the agency's future, as well as NASA's strategic plans dating back to 1986. The resulting report entitled: "NASA's Strategic Direction and the Need for a National Consensus" is a consensus report by the committee.

As I am sure you are aware, NASA has been tugged in multiple directions for the past several years. The agency has had many astonishing accomplishments. Just this past summer NASA landed the Curiosity rover on Mars, and spacecraft such as Cassini (which is orbiting Saturn), MESSENGER (which is orbiting Mercury), and New Horizons (which is speeding toward Pluto) are greatly expanding our understanding of the solar system and our place in it. Both the Hubble and Kepler space telescopes continue to make remarkable discoveries about our universe, with Kepler discovering

dozens of planets orbiting distant stars. NASA spacecraft also collect vital data on Earth's condition and such information is used for many purposes, including improving computer models of how hurricanes form. NASA continues to operate, resupply, and maintain the International Space Station. NASA is also developing new commercial resupply and crew launch capabilities and working on a rocket and spacecraft to eventually take humans beyond low Earth orbit.

Despite these many, important activities, there remains a lack of consensus on the agency's future direction among the United States' political leadership. Without such a consensus, the agency cannot be expected to develop or work effectively toward long-term priorities. In addition, there is a mismatch between the portfolio of programs assigned to the agency and the budget allocated by Congress.

What we found during the course of our deliberations was rather obvious: although NASA develops a strategic plan on a regular basis, the agency itself does not establish its strategic goals. Those are developed by the national leadership, and the key stakeholders within national leadership do not always agree on the goals the agency should pursue.

After considering the current situation facing NASA, the information collected by the committee, and the committee's own deliberations, the committee prepared a final report with the following recommendations regarding NASA's strategic goals and plans:

> **Recommendation:** The administration should take the lead in forging a new consensus on NASA's future that is stated in terms of a set of clearly defined strategic goals and objectives. This process should apply both within the administration and between the administration and Congress, and should be reached only after meaningful technical consultations with potential international partners. The strategic goals and objectives should be ambitious, yet technically rational, and should focus on the long term.
>
> **Recommendation:** Following the establishment of a new consensus on the agency's future, NASA should establish a new strategic plan that provides a framework for decisions on how the agency will pursue its strategic goals and objectives, allows for flexible and realistic implementation, clearly establishes agency-wide priorities to guide the allocation of resources within the agency budget, and presents a comprehensive picture that integrates the various fields of aeronautics and space activities.
>
> **Recommendation:** NASA's new strategic plan, future budget proposals prepared by the administration, and future NASA authorization and appropriation acts passed by Congress should include actions that will eliminate the current mismatch between NASA's budget and its portfolio of programs, facilities, and staff, while establishing and maintaining a sustainable distribution of resources among human spaceflight, Earth and space science, and aeronautics, through some combination of the kinds of options identified below by the committee. The

strategic plan should also address the rationale for resource allocation among the strategic goals in the plan.

To reduce the mismatch between the agency's activities and the resources allocated to it, the White House, Congress, and NASA, as appropriate, could employ any or all of the following four (non-mutually exclusive) options. The committee does not recommend any one option or combination of options, but presents these to illustrate the scope of decisions and trades that could be made.

- *Option 1.* Institute an aggressive restructuring program to reduce infrastructure and personnel costs to improve efficiency.
- *Option 2.* Engage in and commit for the long term to more cost-sharing partnerships with other U.S. government agencies, private sector industries, and international partners.
- *Option 3.* Increase the size of the NASA budget.
- *Option 4.* Reduce considerably the size and scope of elements of NASA's current program portfolio to better fit the current and anticipated budget profile. This would require reducing or eliminating one or more of NASA's current portfolio elements (human exploration, Earth and space science, aeronautics, and space technology) in favor of the remaining elements.

Each of the above sample options, with the possible exception of Option 2, would require legislative action. Every option except for Option 3 would require substantial changes within NASA in order to substantially address the mismatch between NASA's programs and budget. Before implementation of any such options, the advantages and disadvantages, including possible unintended consequences, would deserve careful consideration. For example, if not handled carefully, Option 1 could constrain future mission options or increase future mission costs if unique facilities needed by future missions were decommissioned. Option 1 might also diminish NASA's workforce capabilities if changes in policies were to prompt large numbers of key personnel to retire or seek other employment. To be effective, Option 2 might require congressional authorization for NASA to make long-term financial commitments to a particular program to assure prospective partners that neither NASA nor the Congress would unilaterally cancel a joint program. Option 3, of course, is ideal from NASA's perspective, but its selection also seems unlikely given the current outlook for the federal budget. Option 4 is perhaps the least attractive, given the value of each major element in NASA's portfolio.

The Role and Management of NASA's Field Centers

The success of NASA's past, present, and future endeavors in aeronautics and space would be impossible without the contributions of the field centers and JPL. However, changes in the goals, funding, staffing, and facility requirements of NASA programs, as well as changes in the goals, activities, and capabilities of other government agencies and industry, imply that changes in the operation of the NASA field centers are warranted.

During its visits to the NASA centers, JPL, and from testimony of NASA headquarters leadership, our committee heard that NASA's leadership desires more flexibility in general to manage their facilities. The committee determined that two particular areas where flexibility can be improved are especially relevant:

- *Personnel flexibility.* NASA is restricted by law from performing reductions-in-force (RIFs). The prohibition is currently in the 2010 NASA Authorization Act, which expires at the end of FY2013. Congress could act before then (for instance, in an appropriations act) to repeal that language—or could omit the language from new authorization and new appropriations acts. In addition, NASA could be given the ability to convert civil service positions to contractor positions in select instances.
- *Infrastructure flexibility.* The General Services Administration (GSA) imposes restrictions on government agencies charging less than fair market value for facilities, making it difficult for NASA to dispose of facilities it no longer needs. Easing such restrictions for NASA could save the government money by not having to maintain or demolish buildings no longer required by NASA. In addition, current regulations require that disposed property first be offered to state and local governments, a requirement that could slow down or hinder the ability to find private users. If NASA were given more authority to manage its infrastructure instead of leaving this process to GSA, the agency could take better advantage of opportunities in the private sector.

The committee recognizes that personnel and infrastructure restrictions have been imposed upon NASA, as well as the federal government in general, for many valid reasons. Naturally, any changes would require careful consideration and evaluation by the legislative and executive branches, but they demonstrate that not all solutions require additional money, and legislative and policy changes can play an important role as well.

Recommendation: With respect to NASA centers:

- The administration and Congress should adopt regulatory and legislative reforms that would enable NASA to improve the flexibility of the management of its centers.
- NASA should transform its network of field centers into an integrated system that supports its strategic plan and communications strategy and advances its strategic goals and objectives.

Although the committee lacked the capability and time to conduct the detailed supporting analysis required to make specific recommendations for changes in NASA's infrastructure, the committee did conclude that better coordination with other relevant government agencies is required:

Recommendation: NASA should work with other U.S. government agencies with responsibilities in aeronautics and space to more effectively and efficiently coordinate the nation's aeronautics and space activities.

The Role of International Cooperation
Today it is common to say that all future human spaceflight or large-scale Earth and space science projects will be international. Many U.S. leaders also assume that the United States will take the lead in such projects. However, U.S. leadership in international space cooperation requires that several conditions be met. First, the United States must have a program that other countries want to participate in, which has not always been the case. Second, the United States must be willing to have substantial responsibilities assumed by its partners. In the past, the approach of the United States to international partnership has too often been perceived as being based on a program conceived, planned, and directed by NASA. Third, other nations must be able to see something to gain, in other words, a reason to partner with the United States. Finally, the United States must demonstrate its reliability and attractiveness as an international partner.

> **Recommendation**: The United States should explore opportunities to lead a more international approach to future large space efforts both in the human space program and in the science program.

Conclusion
The committee was impressed with the quality of personnel and the level of commitment of NASA's civil service and contractor staffs and with the superb quality of the work done by the agency in general. However, the committee also heard about the frustration of many staff with the agency's current path and the limitations imposed upon it by the inability of the national leadership to agree upon a long-term direction for the agency. Only with a national consensus on the agency's future strategic direction, along the lines described in this report, can NASA continue to deliver the wonder, the knowledge, the national security, and economic benefits, and the technology that has typified its history.

Thank you for the opportunity to testify. I would be pleased to respond to any questions the Committee might have.

Statement of Task

The National Research Council will appoint an ad hoc committee to assess whether the strategic direction of the National Aeronautics and Space Administration, as defined by the 2011 NASA strategic plan, remains viable and whether the agency's activities and organization efficiently and effectively support that direction in light of the potential for constrained budgets for the foreseeable future. In particular the committee will:

1. Consider the strategic direction of the agency as set forth most recently in 2011 NASA Strategic Plan and other relevant statements of space policy issued by the President of the United States.
2. Consider the goals for the agency set forth in the National Aeronautics and Space Act of 1958 (as amended) and the National Aeronautics and Space Administration Authorization Acts of 2005, 2008 and 2010.
3. Consider previous studies and reports relevant to this task.
4. Assess the relevance of NASA's strategic direction and goals to achieving national priorities.
5. Assess the viability of NASA's strategic direction and goals in the context of current budget expectations and stated programmatic priorities for the agency.
6. Discuss the appropriateness of the budgetary balance between NASA's various programs;
7. Examine NASA's organizational structure and identify changes that could improve the efficiency and effectiveness of the Agency's mission activities; and
8. Recommend how NASA could establish and effectively communicate a common, unifying vision for NASA's strategic direction that encompasses NASA's varied missions.

Any recommendations made by the committee will be predicated on the assumption that NASA's out year budget profile will be constrained due to continuing deficit reduction.

Chairman HALL. Thank you, General, and we will have questions.

It gives me pleasure now to recognize the Hon. Robert Walker, the distinguished former Chairman of the Committee. I listened to Bob as a Democrat, I listened to him as a Republican, and I respected him always. We recognize you for five minutes or as long as you might take, Bob.

STATEMENT OF THE HONORABLE ROBERT WALKER, WEXLER & WALKER

Mr. WALKER. Well, thank you very much, Chairman Hall and Ranking Member Johnson, distinguished Members of the Committee. Thank you for the warm welcome back to this Committee room.

Chairman Hall, I want to first congratulate you for the leadership that you have given to this Committee. You have led the Committee with grace and good humor, and you have really given Chairman Smith a strong base on which to build the Science, Technology, and Space leadership for the future, and I thank you for all that you have contributed here and to the Nation during your career.

If you believe, as I do, that humankind's destiny lies in the stars, and if you believe, as I do, that NASA should be an instrument in the fulfillment of that destiny, then the work of preparing NASA for the daunting challenges of strategy, budget and relevance in the 21st century is truly the work of shaping the future.

The recently released report by the National Research Council does a comprehensive job of detailing the challenges that today's NASA faces: lack of agreed-upon direction, lack of adequate resources to do all that is asked of the agency, aging infrastructure, the emergence of other space-capable nations, the collapse of some international partnerships, the rapid pace of new technology development, and the increasing irrelevance of the aeronautical research program. Much of this landscape cannot be laid wholly at NASA's doorstep but its culture based upon successes of 50 years ago contributes to these problems.

NRC provided four options for addressing an uncertain future. I choose option 2, and to quote again what Ron just told you: "Engage in and commit for the long term to more cost-sharing partnerships with other U.S. government agencies, private sector industries and international partners." Within that option, I will emphasize the public-private partnerships because I believe them to be the best way to obtain the resources so vitally needed to make NASA's missions achievable. I say that mindful of the fact that one of the most important cost-saving measures that could be implemented in our space program would be to use the totality of U.S. assets for U.S. purposes. It makes no sense for NASA to spend billions on development of technology which is already available or under development by other sectors of the government or private industry. Some available technology may have to be modified to meet specific NASA objectives, but the bulk of the costs can be shared.

NASA's basic role must be to do projects that push the envelope of what we know. High risk will lead to new technologies. That

combination of risk and reward will underpin the next generation of space knowledge and products.

Space and technology leadership requires a much broader view of the space community than has been traditional. If NASA is to have the resources it needs to maintain a preeminent world role, it must expand its funding base by reaching beyond a narrow aerospace focus and beyond the authorization and appropriation process on Capitol Hill. I say that latter point with all due respect, but the reality is that no federal budget in the foreseeable future is going to provide NASA with the money it needs to do everything we want it to do. NASA must see entrepreneurship and enablement as key components of its science, technology and exploration programs. NASA can extend its reach and find new financial resources by opening its doors wide to collaborative programs that allow any and all American space entrepreneurs willing to pay for it access to NASA expertise.

There are some positive signs that NASA sees merit in this approach. The Commercial Cargo and Crew programs are encouraging. The use of NASA infrastructure by private sector participant is welcome. But Congress needs to expand the authority to move even more aggressively in this new direction. Too often, the steps taken thus far have been grudging because they really do represent a significant cultural shift. But that shift has been endorsed by several recent commissions that looked at NASA's future and became concerned. The commission I chaired in 2002, one chaired by Aldridge in 2004, and one that Norm Augustine chaired in 2009 all reached the conclusion that commercial activity in the form of public-private partnerships is a key to space leadership. The Aldridge Commission in particular called for broadening the space-related community and restructuring NASA to interact with that community. In turn, it was believed that NASA could benefit directly from the expanded community as it attracted outside investment in its activities and used its people and facilities to enable progress on many space fronts.

A larger network of people and industries with a direct tie to NASA has to be a part of its strategic plan. It begins with buying available services from nontraditional sources. It evolves to a NASA prepared to see multiple nontraditional opportunities for new funding for its programs and activities. We already know there is interest. New companies have been created to provide services to NASA and to pursue business beyond NASA. Those companies should not be seen as rivals or detriments to NASA. They are instead the outgrowth of past NASA successes prepared to learn from what NASA has achieved and poised to grow the U.S. presence in the world space enterprise.

Moreover, thinking in nontraditional entrepreneurial ways potentially can access tens of millions, perhaps hundreds of millions of dollars of private investment in NASA activities. If NASA programs and centers were restructured to take advantage of a flow of private capital, there is no end to potential collaborations. For example, sports teams in the country reap hundreds of millions of dollars in sponsorships without impact on their basic mission. Would anything in science, aeronautics or exploration missions be harmed if the names were attached to particular projects and they

were sponsored? I can't imagine why. These sponsorship dollars could be structured to remain outside the appropriations process, increasing the amounts of money available to NASA and at the same time avoiding to some extent the vagaries of the annual appropriations cycle, and what kind of money is conceivably available? To pick a high-tech example, Formula One racing, the sponsorships there pay for operations costing $200 million to $300 million a year. That is enough for a whole space flight. NASA as an entrepreneur and NASA as a space enabler for growing space enterprise is how we address the resource problems and assure NASA a future that is wholly relevant to our Nation's economy.

Congress will have to be willing to make some adjustments necessary to access that kind of future, but when the Go Daddy rover is traversing Martian terrain, we will be more solidly on our way to fulfilling our destiny in the stars. Moreover, we will have assured that destiny by leveraging our greatest economic asset, the inventiveness of a free market. Thank you very much.

[The prepared statement of Mr. Walker follows:]

The Future of NASA: Perspectives on Strategic Vision For America's Space Program

Robert S. Walker
Executive Chairman
Wexler and Walker

House Committee on Science, Space and Technology

2318 Rayburn House Office Building

December 12, 2012

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Chairman Hall, Ranking Member Johnson and distinguished Members of the Committee, when as Chair of this committee, I authorized the installation of the plagues behind you, the timeless words on the plagues were meant for hearings such as this. If you believe as I do that humankind's destiny lies in the stars, and if you believe as I do that NASA should be an instrument in the fulfillment of that destiny, then the work of preparing NASA for the daunting challenges of strategy, budget and relevance in the 21st Century is truly the work of shaping the future.

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broadening the space related community and restructuring NASA to interact with that community. In turn, it was believed that NASA could benefit directly from that expanded community as it attracted outside investment in its activities and used its people and facilities to enable progress on many space fronts.

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Chairman HALL. And that is just the way it is. Thank you, Mr. Walker. And I thank you too, General.

I now recognize the Hon. Marion Blakey to give your testimony for five minutes, more or less.

STATEMENT OF THE HONORABLE MARION C. BLAKEY

PRESIDENT & CEO, AEROSPACE INDUSTRIES ASSOCIATION

Ms. BLAKEY. Thank you, Chairman Hall, Ranking Member Johnson, and Members of this Committee. Thank you for the opportunity to be here again. I am Marion Blakey, President and Chief Executive Officer of the Aerospace Industries Association, the Nation's premier trade association for aerospace and defense manufacturers.

AIA believes that NASA continues to be a leading-edge investment in our Nation's future. NASA missions and programs save lives. They grow the economy and they inspire the world. I must tell you, AIA has a new report called "Space in our World" and I will make certain all Members of the Committee have a copy, because we are very proud of the fact that we are documenting space systems and how they are woven into the everyday lives of Americans. NASA programs are hallmarks of the character of our Nation and our leadership, and as Americans, we are always looking forward to the next great frontier.

We need to think carefully therefore about changing from current programs. It not only takes a consensus to do so, it takes resources and capabilities, some that we are already building today. Remember that had we not committed to the F–1 rocket engine program in the 1950s, well before President Kennedy's Apollo announcement, we would never have gotten to the moon by 1969. This engine enabled a wide variety of human spaceflight missions, and SLS and Orion will certainly help us take the next steps in space that I think all of us here at this table want.

So how do we keep NASA moving in the right direction? Clearly, NASA needs stable, long-term investment and steady policy goals, and more funding would be better. But we are concerned that constant churn in NASA's programs will lead to less progress. Stability is essential to space mission success and the health of the United States space industrial base. Any examination of NASA's strategic direction must consider the impact to this base, which is also essential to national security space capabilities as well.

So let me take this opportunity, Mr. Chairman, to recognize you as the longest-serving Member of the House Science Committee. By giving NASA solid guidance with the 2010 Authorization Act, you have demonstrated the leadership essential to assure future industry investments and recruit new aerospace talent.

AIA agrees with NASA's three priority goals, which enabled critical space capabilities. First, we must fully utilize the International Space Station, which is a unique national lab. Here, the Commercial Crew and Cargo program provides the quickest way for our Nation to access the ISS. I thought it was terrific to see the success of the first commercial cargo resupply mission just this fall. NASA's commercial initiatives promise to bring down costs and they will free resources for other programs.

Second, NASA's capabilities-based architecture is a realistic approach that is within the fiscal limits that we can then build space systems needed to explore new destinations. To date, significant progress has been made on this program including the delivery of the first Orion capsule to Florida for launch. NASA is also engaging the ISS international partners in innovative ways that expand our ability to completely support exploration together.

Third, we must maintain global leadership in space science. Let us get the Webb telescope into orbit and operating, follow up on our Mars exploration success and replenish our indispensable Earth observation system capabilities. But I must tell you, the spectrum of sequestration concerns me greatly. Not only would it lead to program delays that would prove more costly in the long term but it would also have the immediate impact of putting more than 20,000 NASA contractor jobs at risk. That is the conclusion, and this is very new, by George Mason University economist Steven Fuller in an AIA-commissioned study that we are releasing today, and again I will make certain that all Members of this Committee have this brand-new study because the report highlights the impact of NASA procurement reductions in 11 key states. For example, Mr. Chairman, Texas would lose nearly 6,000 NASA-related highly skilled jobs as a result of sequestration. That is a $320 million impact to the State of Texas.

In conclusion, by focusing investments in support of the 2010 Act, the Congress can ensure the health of our space industrial base and ensure our space program will remain second to none.

I thank you for the opportunity to testify on behalf of the U.S. space industry and look forward to your questions. Thank you.

[The prepared statement of Ms. Blakey follows:]

AEROSPACE INDUSTRIES ASSOCIATION

The Future of NASA: Perspectives on Strategic Vision for America's Space Program

Marion C. Blakey

President and CEO

Aerospace Industries Association

House Committee on Science, Space and Technology
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December 12, 2012

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The Future of NASA: Perspectives on Strategic Vision for America's Space Program

Chairman Hall, Ranking Member Johnson and distinguished members of the committee, thank you for the opportunity to discuss NASA's strategic vision for America's space program. I am Marion Blakey, President and Chief Executive Officer of the Aerospace Industries Association (AIA), the nation's premier trade association for aerospace and defense manufacturers. Before I begin, I would like to thank Chairman Hall for his leadership on the House Science, Space and Technology Committee. Chairman Hall's tenure as chair has been invaluable in promoting our nation's civil space program. I also want to congratulate Rep. Lamar Smith for being selected as the next committee chairman in the 113th Congress; he has some big boots to fill!

The Aerospace Industries Association (AIA) represents over 350 aerospace manufacturing companies and their highly-skilled employees. These companies make the spacecraft, launch vehicles, sensors, and ground support systems employed by NASA, NOAA, the Department of Defense, the National Reconnaissance Office (NRO), other civil, military and intelligence space organizations throughout the globe, and many of the commercial communication satellites. This industry sustains nearly 3.5 million jobs, including much of the high-technology work that keeps this nation on the cutting edge of science and innovation. The U.S. aerospace manufacturing industry remains the single largest contributor to the nation's balance of trade, exporting $89.6 billion and importing $47.5 billion in relevant products, for a net surplus of $42.1 billion. Our nation's aerospace industry strength is, in large measure, due to the investments made by the U.S. government stretching back more than 75 years to the precursor to NASA, the National Advisory Council on Aeronautics which made fundamental research into airfoils, structures, propulsion and other key technologies. NASA's aeronautics investments continue today and while they are less than they were in the past, they still provide valuable investment in fundament aeronautical research.

As you know, the space sector within U.S. industry remains closely impacted by U.S. government space programs. In recent years, our nation's space industrial base has been struggling to adapt to reduced demand by government—especially due to the end of the Space Shuttle program—and downward pressures on DOD, NASA, and NOAA budgets that threaten to exacerbate the risk to the industrial base.

AIA believes that any examination of NASA's strategic direction should include consideration of the health of the U.S. aerospace industrial base to ensure that our national space capabilities for U.S. government and commercial markets remain second to none. By maintaining stability in objectives for NASA programs, and proactively strategizing equitable management of possible fiscal austerity at NASA, the industrial base can be put in a position to succeed for the benefit of our nation's security, science, and exploration programs.

Although AIA is highly supportive of policies and laws that encourage stability in the space industrial base, our support for NASA and the nation's space programs is rooted in a fundamental belief that U.S. space programs have been and continue to be a force of good for our nation.

Space exploration is an irreplaceable, transformative intellectual stimulus for steady, sustained growth in STEM workforces. Frequently those students that were inspired by dramatic space activities become our nation's scientists, doctors, mathematicians, engineers, and technicians in a wide variety of highly technical fields that are critical to U.S. competitiveness.

In a new report, *Space in our World*, AIA outlines how space systems help improve our lives in a myriad of ways. Today, it's not just about spin-offs. Astronauts on the International Space Station are researching vaccines in microgravity lab conditions that can't be replicated here on Earth. Earth observation satellites and the Global Positioning System prepare and guide first responders during disasters like the 2010 earthquake in Haiti. Weather satellites provide advanced warning to the emergency response officials and the public about hurricanes and other severe storms like Hurricane Sandy. Missile detection satellites warn warfighters and civilians of impending danger. Robotic space missions shed light on the laws of nature and help us understand how our planet works.

NASA space programs are an awe-inspiring success story of American character and leadership. Successful space programs not only create a culture of innovation across the nation, they require it. Technological innovations developed for space programs are often later applied to other fields like medicine or emergency management—frequently saving lives on Earth, and growing prosperity for our national economy. NASA space programs also play a key role in garnering soft power and enhancing American leadership abroad. Look no further than the 16-nation partnership on the International Space Station for a high-profile example of American leadership in innovation.

AIA sincerely believes that those who lead in space lead on Earth. As a vital source for new STEM professionals, an exceptional symbol of American strength, a foundry of cutting-edge innovation, NASA is an essential investment in our nation's future.

The need for stability in program objectives

In order to succeed, NASA needs stable long-term investment and steady policy goals; it is this stability in the past that has enabled its greatest triumphs, from the Moon landings and the Space Shuttle, to the tremendously successful Hubble Space Telescope and the ongoing International Space Station. Stability in NASA program objectives is essential to both program success and the health of the U.S. aerospace industrial base.

Another major contributor to our success has been a bipartisan commitment to strong space programs. Space is an arena where the magnitude of the challenges involved requires consistent focus and effort despite partisan power shifts in our legislative and executive branches of government and steady investment despite the economy's ups and downs.

Historically, our space program has exhibited remarkable stability. The Apollo lunar landing – first proposed by President Kennedy at Rice University in 1962 – was actually witnessed in 1969 by President Nixon, the same politician who was defeated by Kennedy nine years earlier.

Similarly, the Space Shuttle program, first approved by President Nixon in 1972 during an economic boom was funded through the energy crisis of the 1970s and finally flown under President Reagan during the deep recession of 1981. During the Carter Administration and the troubled energy crisis period of the 1970s, NASA launched the two Voyager missions on their journeys through the solar system and beyond.

The examples continue throughout our nation's space history – the International Space Station, the largest international scientific and engineering initiative in human history began as a NASA proposal to the Republican President Reagan as a Cold War response by the Western allies to a Soviet space station. It was largely funded and built during the Democratic administration of President Clinton – who was often embroiled in highly partisan battles with the Republican led –Congress. On Capitol Hill, bipartisan consensus has been much more the rule than the exception over this five-decade period even as party control has shifted over time.

More recently, the end of the Space Shuttle Program, the cancellation of the Constellation Program, and delays in agreeing upon a path forward between the Administration and Congress brought significant upheaval to the aerospace industrial base. Nevertheless, AIA believes the NASA Authorization Act of 2010, and the 2011 NASA Strategic Plan that implemented the Act, provided much needed stability through bi-partisan agreement. It is precisely this type of stable, clear and consistent objectives that is essential to assure future industry investments and encourage the recruitment of new aerospace talent.

AIA is mindful of the fiscal challenges facing our nation but while funding in this environment may be difficult, so was space program funding for the Russian government after the fall of the Soviet Union. But they persevered and while still have challenges today, Russia has been able to remain a major space power – witness that today, NASA pays them to send astronauts into space. Similarly, in the US, the Shuttle Program was supported in the stagflation of the '70s and for ISS in the early '90s recession. In both cases, perseverance paid off, and we are confident it will once again.

A balanced approach for human spaceflight

In the case of NASA's long-term strategic goals, AIA agrees with the agency's emphasis on three priority programs, which stand to enable a host of nationally important space capabilities.

First, the ISS is an irreplaceable national laboratory for scientific study that must be robustly utilized in order to provide returns on tax payer investment. Full utilization in the post-Space Shuttle era depends on completing new domestic access to ISS for American

astronauts. NASA's Commercial Crew program will re-establish American access to ISS and end reliance on the Russian Soyuz. NASA's commercial initiatives are already paying off as shown by recent commercial deliveries of cargo to the ISS. In addition to independent access to the ISS, these programs develop new commercial space capabilities and free NASA resources to execute its plans for human exploration beyond Earth orbit.

U.S. industry is already investing its capital and innovation to support this new future, and U.S. government agencies and the Congress have also taken key steps that have helped foster these new initiatives. Stability in these programs is needed for industry to demonstrate to investors and industry that government will live up to its commercial commitments.

As the NRC report notes, a consensus has not been widely agreed upon for human space exploration in the out years, however, first, the Orion Multi-Purpose Crew Vehicle and the Space Launch System (SLS) are the essential building blocks for NASA to go beyond Earth orbit, no matter what the destination. Significant progress is being made daily on these programs at our companies. In July, the first Orion capsule for flight was shipped to Florida for launch. Just last Wednesday, the upper stage engine for the SLS was test fired for over 1,200 seconds. Developmental progress of the Orion and SLS must continue to ensure these capabilities are available for mission sets beyond the planned 2017 and 2012 missions. Bringing new launch vehicles and spacecraft on line takes time; strong progress can be made now even if the timeline of destinations is not yet outlined in detail.

For example, the U.S. government's anticipated need for a large and powerful rocket engine initiated the F-1 rocket engine program in the 1950s – well before President Kennedy's Moon Program announcement. Although it was not yet known how the F-1 would be used at the outset of development, the program began in anticipation of likely future needs. In fact, the F-1 took over 7 years to develop, and would never have been ready to enable Apollo without this early start. The F-1 of course, would later power the Saturn V launch vehicle for the Apollo Moon missions, Skylab missions, and Apollo-Soyuz mission – none of which had been defined when F-1 development began in 1955 – three years before NASA was created. The basic F-1 engine capability was foundational to a number of mission profiles for the human spaceflight program, and the Orion and SLS will be used for a variety of beyond Earth orbit destinations that have yet to be defined.

By continuing development of Orion and SLS, work force capabilities and the industrial base are not only preserved but grown. Orion has made major progress leading up to its first test flight in 2014. The core stage of the SLS is well into a technical design and manufacturing phase, and former Space Shuttle engines are ready for utilization by SLS. Continuing SLS and Orion are necessary to enable a human spaceflight missions beyond Earth orbit to a variety of destinations, sustain the health of the space industrial base needed for national programs, and inspire new generations of young people.

In 2009, due to funding and program challenges, the Constellation human exploration program was cancelled, and in 2011 the Shuttle Program ended. Further interruption of the human spaceflight program would be devastating for the program and the industry, yet

funding prospects are at risk. Although the Orion and SLS budgets have planned for an austere environment, repeatedly starting and stopping programs risks the industrial base–many parts and component suppliers to larger prime contractors simply cannot absorb major acquisition disruptions when the order volume of components is already so low in the space industry. Many suppliers design and fabricate unique, one-of-a-kind parts for the entire space industry. Additional program instabilities will put such suppliers out of business, and raise the fixed cost for other U.S. government space programs, just as Shuttle's retirement raised costs for DOD solid rockets. Finally, major primes or other major companies could decide to exit the business and seek more stable opportunities elsewhere, depriving NASA of their unique capabilities.

The current Orion, SLS, and Commercial Crew program structure is part of a bi-partisan agreement between the White House and the Congress. These systems fulfill the Columbia Accident Investigation Board's conclusion that exploration beyond Earth orbit is a fundamental reason for human space exploration. This perspective also reflects widespread consensus, codified by law that the United States should enable an expanded commercial presence in, and access to, low-Earth orbit, as elements of a low-Earth orbit infrastructure. In order to achieve this end and protect the space industrial base, the Orion, SLS, and Commercial Crew programs should continue as planned.

Maintaining global leadership in space science

Space science programs at NASA have nurtured crown-jewel capabilities in our space industrial base while answering important questions about our planet, our solar system, and our universe. The agency appropriately emphasizes the need to continue this proud legacy with steady investment for future missions, especially when it comes to the NASA priority science mission, the James Webb Space Telescope (JWST). JWST will be NASA's premier telescope for answering bold, paradigm-shifting questions, including questions of the origin and nature of the universe, galaxies, stars, and planets. Already the JWST primary mirror is complete, bringing the program one step closer to uncovering ground-breaking, new science insights.

It is important to recognize that U.S. scientific leadership is not a given, it is dependent on the will and commitment to fund innovative space science missions. If new space science missions are not built to carry the torch of progress from previous missions, U.S. world class research programs can be overcome by more aggressive international programs. The benefits of space science investments are far-reaching, and in many ways our leadership pays dividends in knowledge, prestige, and further innovation.

Although there is widespread support for strong space science programs at NASA, considerable stress can sometimes be placed on space science programs to cut costs and speed development. It's important to remember that as the scientific community looks to answer bold, paradigm-shifting questions, the complexity of space science missions can grow to meet these challenges. As these missions become more sophisticated, the need for steadfast U.S. government commitment becomes all the more critical to success. The resolve of the U.S. government must remain strong to stay the course through to success.

Many space science missions face enormous challenges in accomplishing technical feats that have never been done before. They must also grapple with limited capacity of affordable, domestic space launch systems to low Earth orbit. Couple these challenges with an occasional launch failure and annual budget constraints, and an environment has been created in which space science missions face a daunting future. Look no further than the Earth observation community for evidence of an increasingly difficult situation for space science. The National Research Council recently reported, "that the nation's earth observing system is beginning a rapid decline in capability, as long-running missions end and key new missions are delayed, lost, or cancelled."[1] With such an increasingly difficult environment coalescing on space science, it is all the more necessary for the U.S. government to maintain a steady resolve for future mission development. The space industrial base that has enabled incredible U.S. achievements in space science can only be sustained for future missions if a steady commitment is maintained by the U.S government to continue these missions.

Interagency Partnerships

NASA's unique capabilities and competencies are world renowned, and incredibly important to other agencies within the U.S. government. NASA's role in reimbursable government agreements is important to the continued operation of several critical government programs. Of special importance remains NASA's reimbursable work for the National Oceanic and Atmospheric Administration (NOAA) on weather satellites. As the developer of the nation's weather satellites, NASA plays an essential part in protecting our safety and our economy from natural catastrophes. Additionally, NASA is also a key partner in the operation of the Landsat program at the U.S. Geological Survey at the Department of Interior. Landsat is a vital Earth observation system for U.S. Government land and coastal surveys. NASA also maintains a partnership with the Department of Energy to ensure the nation's deep space exploration systems have access to non-weapons grade plutonium-238. Without such fuel, space exploration to the outer planets and beyond becomes impossible. AIA encourages the continuation of these reimbursable agreements to meet important national requirements.

International Partners in Space

From the Canadian Tele-robotic Arm and the European Spacelab on the Space Shuttle to the truly International Space Station (ISS) as well as a wide range of programs in between including the Cassini/Huygens mission to Saturn, the SOFIA infrared telescope and even the Curiosity Rover now on Mars, international cooperation has been essential to doing truly great things in space while providing value to taxpayers of all nations and improving relationships among the partners. International partnerships also integrate well with a

[1] Report Warns of Rapid Decline in U.S. Earth Observation Capabilities; Next-Generation Missions Hindered by Budget Shortfalls, Launch Failures," http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=13405, Accessed 13 June 2012.

capabilities based exploration architecture as new partner contributions can be added over time based on partners' technical and financial ability to contribute. We see international partnerships as essential to NASA's future success with proper regard to national security and other national considerations, including the potential impacts on the U.S. industrial base. AIA will seek to work with NASA to help understand the industrial base consequences of cooperative agreements and assure that such agreements are truly win-win propositions for both sides.

Managing fiscal austerity

In addition to stability in program objectives, budgetary conditions at NASA also threaten to affect program effectiveness and space industrial base health. As of now, the Budget Control Act is law, and without a legislative solution, across-the-board cuts to NASA will begin in January 2013. A cut of 8.2% to NASA's budget next year would immediately eliminate $1.6 billion from the agency and significantly affect its strategic direction. Should the 8.2% cut be enacted, the impact on programs would likely be magnified by the NASA Authorization Act of 2010 that forbids NASA employee layoffs through FY13.

In a July 2012 AIA report on the effects of the Budget Control Act on federal agencies, it estimated that sequestration will put at risk 2.14 million jobs in 2013 alone.[2] Today, AIA released a report highlighting the economic impact from sequestration on civil space programs. The analysis conducted for AIA by Dr. Stephen S. Fuller, Dwight Schar Faculty Chair and director for Regional Analysis at George Mason University, revealed that an 8.2 percent cut to the agency's budget would amount to a loss of over 20,000 jobs nationally in 2013 alone. Additionally, the NASA Authorization Act of 2010 prohibits any cuts to the civil servant work force through fiscal 2013. As a result all of these lost jobs would come exclusively from the private sector.

The loss of more than 20,000 jobs would be significant – many of these are scientists, engineers, and technicians that design, manufacture, and operate our nation's spacecraft. In short, these are the best high-skilled jobs our economy has to offer. Such a dramatic collapse in our technical workforce would equate to a major loss in national capability. It's important to remember that much of the same space industrial base that serves NASA also provides essential government capabilities for communications, weather observation, remote sensing, GPS, and other satellite systems that are an integral part of our nation's infrastructure and economy. It should also be noted that an 8.2 percent reduction in the NASA budget would be multiplied by the number of subcontractors, many of which are small and disadvantaged businesses.

A NASA budget sequestration would also deal major damage to those regions with high concentrations of aerospace activity around the country, better known as industry clusters.

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[2] Fuller, Stephen S., *The Economic Impact of the Budget Control Act of 2011 on DOD and Non-DOD Agencies.* July 17, 2012. Retrieved from http://www.aia-aerospace.org/assets/Fuller_II_Final_Report.pdf

Many space companies directly support NASA missions by designing and building spacecraft, and frequently co-locate with NASA centers. Other companies that support NASA are significant economic drivers in other key aerospace clusters that have no NASA center. A NASA sequestration would result in far reaching and lasting losses for major aerospace clusters beyond the space industry. The following appendix tables outline several key space clusters around the country that stand to experience crippling losses from sequestration.

State Impacts of NASA Procurement Spending Reductions under the Budget Control Act of 2011
Fiscal Year 2013
(dollars in thousands, jobs are actual number)

The eleven states examined in this table account for 91.8% of NASA procurement funding.

State	Direct Impact	Total Output *	Labor Income	Jobs Losses
Texas	$320,171	$751,121	$272,799	5,610
California	293,443	699,393	215,676	4,586
Colorado	125,582	291,741	107,301	2,121
Maryland	127,282	238,974	78,022	1,520
Alabama	75,870	153,693	56,661	1,369
Florida	72,100	158,942	59,563	1,366
Utah	47,213	106,768	39,411	963
Virginia	52,524	108,626	37,052	713
Ohio	26,871	53,952	18,578	429
Mississippi	25,990	43,583	15,215	374
Louisiana	24,826	44,415	15,865	359
State Totals	$1,191,873.80	$2,651,208.80	$916,143.60	19,410

Source: George Mason University Center for Regional Analysis
*Reduction from Gross State Product.

National Impact of NASA Spending Reductions under the Budget Control Act of 2011 Fiscal Year 2013
(dollars in thousands, jobs are actual number)

Nationwide	Direct Impact	Total Output*	Labor Income	Job Loss
Totals	$1,298,190	$2,843,651	$1,018,358	20,682

Source: George Mason University Center for Regional Analysis.
*Reduction from Gross Domestic Product.

Regardless of the end result of the Budget Control Act this month, an austere federal budget environment is likely to be in place for some time. AIA therefore believes that NASA should take on equitable strategies maintaining program stability and the health of the aerospace industrial base in an era of leaner budgets.

Throughout NASA's history, from Mercury to Space Shuttle, the agency has seen major transitions from program to program. Although the agency has largely managed its workforce according to its budget and mission, there are some instances where the agency structure has not been specifically crafted for major programs at hand—sometimes with few modifications of the civil service workforce in response to program restructures, cancellations, or developments.

During such eras, the civil service workforce has remained steadily in place as the industrial partners to NASA programs face the brunt of program fluctuations. For example, following the Apollo Program, the agency budget declined by nearly 60%, while the civil service workforce reduction was only about 30%. In the modern era, from 2006 to 2012, the NASA Aeronautics budget went down by about 40%, but staffing levels are only down by 5%.

Despite the fact that it is aerospace companies that make the spacecraft, launch vehicles, sensors, and ground support systems employed by NASA, it is the industry workforce that absorbs almost all of the workforce layoffs during lean years. This puts the space industrial base in a precarious position. The industrial workforce that disproportionately absorbs program changes and cancellations must still serve the needs of NOAA, DOD, NRO, and other government agencies engaged in space operations.

As we face a likely era of lean federal budgets, AIA recommends that approaches be considered which better allow NASA to meet its strategic goals. For example, AIA urges

NASA to widely pursue commercial, academic, and government agency partnerships as a way to maintain and spread the cost of very expensive and unique assets, while making these assets available for NASA programs. And it urges NASA to fully utilize existing authorities (enhanced use lease, etc.) in doing so. The human and physical assets of NASA and its supporting industrial base represent a large and critical national investment that needs continual maintenance and upgrade. As pressures on budgets continue, sharing these assets is an effective way for NASA to strengthen the U.S. economy, to reduce cost of asset ownership, and to keep the assets available for the space program of the future.

Additionally, to allow NASA the freedom to appropriately adjust to space program realities, AIA recommends that future NASA Authorization Acts not include restrictive provisions on NASA civil service workforce like those seen in the NASA Authorization Act of 2010.

Conclusion

AIA is highly supportive of NASA's strategic direction, and the balanced, bipartisan approach that was agreed upon by the White House and the Congress in the NASA Authorization Act of 2010. Without the historically unique priority and resources of the Apollo program, we may have to settle for an incremental exploration program with greater international and private sector involvement, not a dramatic "Moon shot." But this does not mean we should abandon human exploration until all our problems are solved and the Treasury is flush with cash. While not as dramatic, such an approach can still produce a solid exploration program with real STEM education value while producing the technological and soft power benefits of U.S. space leadership—attracting talent and capital to our shores and add to our international reputation as a leading power in the 21st Century.

By steadily investing in the goals of the 2010 Act, the U.S. government can ensure the health of the U.S. space industrial base, while simultaneously building future space successes that have come to define American character and leadership. The resurgence in new human spaceflight system development is incredibly impressive: no other nation in the world is developing such a wide breadth of systems in the public and private sector. The continuous landmark successes in space science are unprecedented in the history of civilization, re-shaping our entire understanding of the universe. By building upon these successes with continued investment and policy support for the goals in the 2010 Act, the U.S. government can be assured its space program will remain worthy of a great nation.

I thank you for this opportunity to testify on behalf of the U.S. space industry and I welcome the opportunity to answer any questions that you may have.

Chairman HALL. I want to thank you for good testimony and for your accolades. I am not the longest-serving, I am just the oldest, and if John Dingell would cooperate with me, I will be the oldest one of these days here, and I will yield you another hour for your kind words if you like. Good testimony, and we thank you.

Now we have Dr. Zurbuchen for your five minutes. Doctor, I recognize you, sir.

STATEMENT OF DR. THOMAS ZURBUCHEN PH.D, PROFESSOR FOR SPACE SCIENCE AND AEROSPACE ENGINEERING, ASSOCIATE DEAN FOR ENTREPRENEURIAL PROGRAMS, UNIVERSITY OF MICHIGAN

Dr. ZURBUCHEN. Mr. Chairman and Members of the Committee, thanks for the opportunity to testify today. My name is Thomas Zurbuchen, a Swiss name from the mountains in Switzerland, and I am a Professor of Space Science and Aerospace Engineering at the University of Michigan. I run a research group with six space instruments in space right now and we are operating those and developing breakthrough science that is published in premier journals around the world. I am also the Associate Dean for Entrepreneurial Programs and concerned about spreading of innovation and entrepreneurship in our educational mission at this university and universities around the country.

This is a period of limited resources, and we need to focus to position ourselves for better times. The way to do this is to ensure that a talented workforce will be available and disruptive innovations and technology breakthroughs are pursued. We need to do this through low-cost and modest-sized missions. The talented workforce and the innovations will be developed primarily by universities and industry, particularly small businesses and not primarily NASA centers. Hence, we need to pursue a strategy in which universities and industry as well as NASA centers are fully engaged.

Today I want to focus on two key aspects of this strategy: the focus on people and the focus on disruption, innovative disruption, and I want to briefly talk about the balance, the program balance that is responsive to both of them. The number one priority of the space program and especially its science program should be talented people. Every mission in space, great or small, is carried out by people, not paperwork. We need people and their know-how. We have to ensure that NASA's space missions have access to the very best talent. How do we do that? First, we must recognize that top talent does not just hang out and wait for better times. Builders want to build. Innovators will innovate. And NASA leadership must be focused not just of the glory of days past but the aspirations and dreams of the innovators of the future. Second, some of this talent will be at NASA centers but most of the talent will be in academia and industry, particularly in small companies. Therefore, encouraging competition in emerging space industries will keep top talent focused on efforts that ultimately will aid this Nation in achieving its most ambitious goals through both technical innovation and reduced cost.

The next priority in addition to people is innovative disruption. Disruption is good. Disruptive programs overturn old paradigms, create new markets and engender new value systems. These programs focus on smaller spacecraft, rapid turnaround missions, and I am convinced that science programs with these kinds of priorities will look different than the ones that we are building today. Consider, for example, the RAX program at the University of Michigan, which built and launched two CubeSats within two years for less than a million dollars. These NSF-funded tiny satellites make new measurements probing the origins of space weather, especially in high latitudes, the auroral regions, and the first one failed a few weeks into orbit. It is tough to do this, and the second one has now made measurements for over a year—research that is published in our premier journals. Also, this mission has provided hands-on experience for 50 of our best students. Many of these leaders work at SpaceX and some of the new space companies in fact being leaders of certain domain expertise really shortly after graduating and some of them work at NASA JPL and other NASA centers. They got experience that most students in the United States did not. RAX is all about innovative disruption, training of the world's best talent and for our space program.

So how do we build a program that is responsive to these kind of constraints, and I do believe that a program like this requires small and responsive missions and projects from suborbital to large, strategic missions. It is a big priority, particularly to invest in modest-sized and principal investigator-led missions such as Discovery or New Frontiers or Venture-class missions, depending on the respective community. These missions have provided the best value for the money invested. That is the type of program that research resulting in NASA's first Nobel Prize was conducted and it is the type of program that built the spacecraft currently orbiting planet Mercury, and one of my censors is on there

Consider, for example, University of Michigan's CYGNSS mission that was recently selected that is focused to eliminate one of the biggest uncertainties and predictions of big storms such as hurricanes and some of the storms that bring tremendous amounts of rain here sometimes, the uncertainty that relates to the strength of these storms. The science payload is approximately 100 times smaller in mass, in price and in power than conventional satellite measuring instruments which enables an entire constellation of these sensors to be flown at lower cost. So the use of this constellation reduces the revisit time and therefore the time resolution of the most pivotal measurements of these wins from days to hours, which is needed to observe the inner core processes of these storms. So these short-term priorities, however, must be balanced and aligned with big bets and big thinking worthy of NASA. NASA science should stretch our imagination, stimulate our thinking and demonstrate leadership worldwide. We must remember that the work that we do is not purely scientific, technological or economic or military based. The prime discoveries that further out understanding of the cosmos have fueled and inspired the human imagination across all cultures and all times and I believe will do so in the future.

Thank you so much.

[The prepared statement of Mr. Zurbuchen follows:]

Testimony of

Dr. Thomas H Zurbuchen

Professor, Space Science and Aerospace Engineering

Associate Dean, College of Engineering

University of Michigan

Mr. Chairman, Ranking Minority member, and members of the Committee, thank you for the opportunity to testify today. My name is Thomas Zurbuchen and I am a professor of Space Science and Aerospace Engineering at the University of Michigan where I am also the Associate Dean for Entrepreneurial Programs. In this function, I am responsible for bringing innovation to large-scale programs within the College of Engineering and also across the university campus. Being the first university graduate in my family, I moved from Switzerland to the U.S. for one reason: to do meaningful work in space within a nation and a university that supports it. Has this ever been a great choice: one of my instruments is currently in orbit about the planet Mercury; two others make measurements near Earth and aid in predictions of violent space weather events.

At the same time, I have also been witness to the progressive decline of the agency that was my childhood dream, and the passion of my academic pursuits. While it is easy to romanticize NASA's past, such as the heroic missions of Apollo, we must remember that our predecessors faced the same challenges we currently face: defining the purpose and meaning behind the exploration of space within a society that does not always see a tangible benefit; being responsible for budgeting resources to protect and serve a nation, while also being responsible to the great quest for knowledge and visionary dreams that unite all of humankind.

We are in a period of limited resources, and so progress will be inevitably limited. This is an ideal time to position ourselves for better times. The way to do this is to ensure that a talented work force will be available, and that innovations and technology breakthroughs are pursued, so that when we come out of this period of limited resources we are positioned to advance rapidly. The talented workforce and the innovations will be developed by universities

and by industry, particularly small businesses, not by NASA centers (any more than most large industries are capable of innovating). Hence, we need to pursue a strategy in which universities and industry are fully engaged in ensuring a promising future for the space program.

Let me address the first question about the priorities lawmakers should consider when evaluating future NASA plans, especially plans for NASA's science program.

Science investments should be focused on the following three primary criteria.

1) Science and engineering excellence and leadership: Science needs to be prioritized in time and also to give emphasis to certain areas of NASA research at certain times.

2) Societal benefits: these benefits are in the long term and short term. Some of them relate to NASA missions and needs, but many programs have impact well beyond NASA and open up economic opportunities, contribute to the health and well being of our citizens and in some cases even save lives.

3) Build a talent pool of innovators: NASA's space science missions need access to the best talent; and breakthrough innovations and new technologies are developed by people. Some of this talent is at NASA centers, but most of it is in academia and in industry, especially in small companies. I will get back to this point later.

I believe the first objective - science and engineering excellence and leadership - is well addressed by the advice NASA and Congress receives from the National Academies. I was vice-

chair of the most recent decadal review focused on solar and space physics and I believe that process really works to identify and promote the best science and also engineering objectives. With regard to the second objective, NASA's space science programs have historically brought tremendous societal benefit. Earth science missions provide vital information in areas ranging from weather and climate to land resources to natural disasters, and spacecraft in solar and space physics are used to make predictions of space weather that can disrupt technologies on Earth. Research that can create such societal benefits strengthens the rationale of those missions and programs.

I am convinced, though, that the third objective – building a talent pool of innovators – in many ways will have the most effect on our leadership position 10 or 20 years from now. We need a workforce whose aspirations in space are not diminished by the doom and gloom sometimes espoused by our leaders as they look back to "the good old days." We need a talent pool of impactful engineers and scientists who are ready to develop the space systems of the future. Top talent does not just hang around and wait for better times – innovators want to start moving the ball now!

I am convinced that a science program at NASA with these kinds of priorities will look different than what we are building today. It would be one that focuses on smaller spacecraft, and rapid turnaround missions. It's not "faster, better, cheaper" – the mantra of a NASA administrator of years past – but it is "faster, cheaper, disruptive". Disruption is good! Disruptive programs overturn old paradigms, create new markets, and engender new value systems. Missions to be developed should be of diverse sizes and implemented at a cadence

appropriate to their cost and complexity. Implementing missions in this balanced approach best engages our community and optimizes the science return for a given level of investment. Some of these investigations may be in the suborbital realm, some of them through what we call "CubeSats", some of them through small spacecraft that can be built with an increased risk profile, but all the missions should develop and provide to the space community and industry tools that are game-changing.

How can NASA and its stakeholder community reach consensus on identifying and preserving capabilities necessary for future use?

One of the most challenging aspects of NASA's research program is the mismatch between its strategic objectives and its program. I do not see a way around addressing the issue of consensus without addressing the key question behind each and every organization: What is the most important thing that NASA does? That strategy can be far ranging, but it must have measurable and exciting milestones along the way. Without such a consensus goal, a point in the sky we are marching toward, it is going to be very tough to create consensus – very tough, and perhaps impossible.

I would, however, make a point about the difference between technology and know-how. We can document technology with drawings and with specifications. We can even record in pictures how a particular piece of hardware is assembled. But it turns out that it is almost impossible to reliably build any technology based on such a record. We need know-how that is only achieved through experience, from actually working on the space instrument or the data

inversion problem. That know-how is an important part of keeping capability alive, often more important than any engineering drawing or process report.

What priorities should policy makers consider when evaluating appropriate allocation of resources to maintain balance?

The priorities should be focused on outcomes that are both strategic and worthy of NASA and its proud history. When we come out of this economic downturn, we want to be the most innovative and most impactful economy of any competitor anywhere. I believe that this goal will be achieved through an investment strategy that has both near-term and long-term elements.

In the near term, the first priority is getting the maximum scientific value out of our existing assets. The first aspect of this will be to grow the science output of our investments, building upon our current leadership position and increasing the lead between our competitors and us.

The second priority is growing innovative activities and an entrepreneurial mindset in our science and engineering communities. This priority can be pursued by implementing a diversification of NASA's portfolio to support investments that are focused on disruptive technologies – new approaches to get to space and to achieve success there. These investments should encourage calculated risk-taking and the development of a pool of innovation that enables NASA's long-term strategy, and also attracts and trains the talent we will need to implement that strategy. Investments should go to the entire NASA community, within Centers, but particularly within Academia and Industry. History shows that it requires all

three to create the leadership and to get the most economic return from government investments.

The third priority would be to invest in modest-size, and principal investigator led programs—known variously as Discovery-, Explorer-, or Venture-class, depending on the respective community. These missions have provided the best value for the money invested. That's the type of program where the research was conducted that resulted in NASA's first Nobel prize, and that's the type of program that built the spacecraft currently exploring Mercury!

The fourth priority is about big bets. NASA science needs these big bet programs to stretch our imagination. Landing a small car softly on Mars, crossing into our galactic neighborhood, observing the universe all the way back in time to its infancy – these crowning achievements do not come from small assets, but they stimulate our thinking and show leadership worldwide. However, these big-bet projects cannot squeeze out the other three priorities.

If you read the priorities of the recently released decadal strategy of the solar and space physics community, you will notice a deep alignment and consistency with this prioritization.

Thus, the most important dimension of balance is in the scale of programs! The future of space—future talent, future technologies—will be made in low-cost small satellites, such as "CubeSats", and modest size missions, such as Venture class, and Explorer missions. If we fail to recognize balance in scale, we will cede the future to others. I can report to you that a new generation, here in the U.S., is poised to develop the disruptive technologies of the future and

lead the U.S. to being the innovative, most impactful competitor in space, in the world. Let's turn them loose. Let's turn them loose to innovate, to take risks, to become leaders. What will follow will be scientific and engineering excellence, what will follow will be new societal benefits, and what will follow, in its own course, will be a broad national consensus of support for our civilian space program.

I cannot forget that it was the work NASA and this committee did thirty years ago that captured my imagination and changed my life forever. I keep an old science book in my office to show to my students. It talks about a new project—Voyager—that NASA was planning to explore the outer planets. This mission—one of the proudest in NASA's history—was in the news again last week. I think it is the dreams and imaginations of our youth that carry us through the difficult choices we inevitably make as adults, and I believe it is the work this committee will do in the next few months that will define the next chapter of space exploration and determine whether the US will continue to be the place that inspires the next great generation of scientists and explorers. My hope is that by focusing on people and disruption, utilizing the best talent here and abroad, and by leveraging the unique strengths of our government, industry, and academic institutions, we can and will.

I look forward to your questions.

Appendices

1) Example of CubeSat mission: RAX
2) Example of CYGNSS, a disruptive mission architecture
3) Information about decline of graduate students to get hands-on experiences in space research

1) Example of CubeSat Mission: RAX

The Radio Aurora Explorer (RAX) is the first NSF-funded CubeSat mission with PI James Cutler (University of Michigan). Two CubeSats were launched in 2010 and 2011 onboard U.S. Department of Space Test Program (STP) missions from the Kodiak Launch Complex in Alaska. RAX is capable of carrying out a mission that was previously only considered to be done with larger satellites: RAX's primary mission objective is to study large plasma formations in the ionosphere, the highest region of our atmosphere. These plasma instabilities can create magnetic field-aligned irregularities (FAI), which are dense plasma clouds known to disrupt communications between Earth and orbiting spacecraft. To study FAI, the RAX satellites utilize a large incoherent scatter radar station located in Poker Flat, Alaska (known as PFISR). PFISR transmits powerful radio signals into the plasma instabilities, which then scatter in the FAI and are received by the orbiting RAX spacecraft. The signals are then processed by RAX's onboard computer and transmitted back to Earth for scientific analysis.[1]

[1] From James Cutler and his entry in Wikipedia, as well as http://rax.engin.umich.edu/

In orbit now for over a year, RAX continues to make novel measurements of the Earth space environment and first results have been published in the scientific literature. During its design and development, RAX has employed over 50 graduate and undergraduate students and provided experiences that already have enabled careers and changed lives.

2) Example of CYGNSS, a disruptive mission architecture

A major uncertainty with hurricane predictions at present is forecasting their intensity. The uncertainty results from a lack of measurements (in particular, surface wind speed) in the inner core of the storm, which is where the dynamical processes occur that determine storm genesis and intensification. The necessary inner core measurements are made today by the NOAA "hurricane hunter" aircraft near the U.S. coast. They are not possible from satellites for two reasons: 1) they require penetration through the intense precipitation that is present in the eye-wall and rain bands; and 2) they require very frequent measurements to capture the rapid intensification phase of the storm (timescale of hours). Current satellite measurements can't see through the heavy rain and they have orbital revisit times of days.

Only hurricane hunter aircraft are a viable solution today – a single spacecraft approach with high accuracy using radars and/or lidars is much more expensive. Hurricane hunter aircraft are one reason why the Hurricane Sandy forecast at landfall near New York City was so accurate. The aircraft were repeatedly overflying the storm as it made its way up the eastern shore of the U.S. Further from land, and in the Pacific Ocean, only conventional satellite observations are available and the quality of the intensity forecasts is much worse.

The CYGNSS EV-2 [2]mission uses a constellation of GPS surface reflection receivers to measure the ocean surface wind speed in all weather conditions, including extreme precipitation levels. This type of remote sensing is fairly new but has been well established on aircraft in hurricanes. The science payload is approximately 2 orders of magnitude lower in price, mass and power than conventional satellite wind sensing instruments, which enables an entire constellation of them to be flown for a low cost. Use of a constellation reduces the revisit time from days to hours, which is what is needed to observe inner core process dynamics. The two requirements for inner core studies (penetration through heavy precipitation and frequent revisit times) are uniquely enabled by this new approach.

CYGNSS should result in a fundamental improvement in our understanding of the inner core process of hurricanes and, as a result, significantly improve our intensity forecast skill. And it will do so not just in the tropical Atlantic near the U.S. coast, but globally. It will also mark the first time that a small satellite constellation architecture is used for space-borne Earth science. This architecture has major cost savings implications for future Earth science missions.

3) Information[3] about decline of graduate students to get hands-on experiences in space research

"Our policymakers need to acknowledge that the nation's apathy toward developing a scientifically and technologically trained workforce is the equivalent of intellectual and industrial disarmament and is a direct threat to our nation's capability to continue as a world

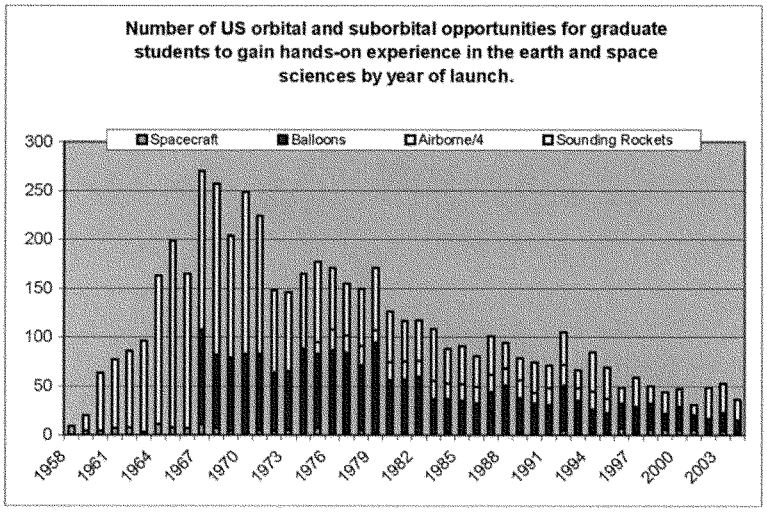
[2] http://aoss-research.engin.umich.edu/missions/cygnss/
[3] This is courtesy of the University Space Research Association

leader." (The Report of the Commission on the Future of the U.S. Aerospace Industry, November 2002)

"At present, there are insufficient methods for students to acquire hands-on experience in the scientific and technical disciplines necessary for space commerce and exploration." (Commission on Implementation of United States Space Exploration Policy (the Aldridge Report), June 2004)

There is a significant deficit of scientists and engineers in the United States with meaningful hands-on experience with space instrumentation and space systems, which is jeopardizing the ability of the nation to maintain a vigorous presence in space into the future, regardless of whether we are in space for reasons of commerce, exploration, national defense, or scientific research. This deficit leads not only to a loss of capability, but also to escalating costs of many of the space systems vital to the nation's security and industrial competitiveness.

The scientists and engineers who learned their trades during the first decades of the space age have reached or are nearing retirement. These were exciting years for a young person to enter space research, and space attracted many of the best young scientists and engineers. These years were marked by frequent launches of smaller missions many of which were led by university-based teams that included graduate students. These students got plenty of hands-on experience, and learned first hand the difficulties of designing and constructing an experiment or engineering system that would operate reliably in space. Many students also learned from designing and building experiments for smaller, suborbital flights on rockets or balloons, or by observing with an airborne telescope.



The chart shows that the number of these opportunities peaked in 1968, at the height of the Apollo program. Since then the number of student opportunities provided by spacecraft missions, rocket and balloon fights and airborne observatory sorties has diminished from over 250 per year to consistently less than 50 per year. Most graduate students now never have an opportunity to do hands-on science. Instead, the vast majority of science PhD students analyze data obtained from instruments they have never seen and thus have only a vague idea of how they work or how they might malfunction. They certainly don't learn the important skills needed to conceive of, and to help design and construct a space experiment.

The chart hides another phenomenon. As space missions have, necessarily, become more complex, they also take longer to design and construct. The increasing complexity means

that fewer universities have the resources and capabilities to manage the complexity, so increasingly missions are being run by non-academic laboratories and research centers. The mission timescale is now significantly longer than a typical graduate student remains in school. Both of these effects significantly decrease the likelihood of graduate student involvement, exacerbating the problem.

Chairman HALL. Thank you, Dr. Zurbuchen. Good advice, and well presented. Thank you, sir.

At this time I recognize Dr. Pace for your five minutes.

STATEMENT OF DR. SCOTT PACE, PH.D, DIRECTOR, SPACE POLICY INSTITUTE, THE GEORGE WASHINGTON UNIVERSITY

Dr. PACE. Thank you, Mr. Chairman and Ranking Member for this opportunity to discuss the important topic of NASA's strategic direction.

It has been noted that the NASA Strategic Plan does not drive NASA budget requests or the allocation of relative emphasis to activities within those requests—exploration, science aeronautics. As such, it is not surprising that there are numerous disconnects between the stated policies, approved programs and their actual funding. The technical and budgetary risks facing the agency are the most visible symptoms of deeper policy and management disconnects between the White House and Congress. Such disconnects are not inevitable and can be resolved by the White House and Congress as well as NASA working together, and as often stated, budgets are policy and NASA budgets are really a more accurate reflection of de facto national policy than the NASA Strategic Plan is.

The NASA budget is a political choice. It is a reflection of what we value as a society. The Obama Administration's stimulus program was greater than NASA's budget cumulatively from 1958 to 2008 in constant-dollar terms. The United States sent humans to the moon, built and operated a space shuttle fleet for 30 years, explored the solar system and contributed its share of the International Space Station for less than the cost of the American Recovery and Reinvestment Act. The point of such a comparison is not that space is inexpensive but rather that in today's environment, sustaining discretionary expenditure for civil space exploration will be challenging unless there is a clear rationale linking such efforts to broader national interests that could be supported in a bipartisan manner over many years.

What I hope to convey in my written testimony was that while NASA faces serious challenges, particularly in human space exploration, a way forward does exist to put the agency on a more stable and sustainable foundation that will advance U.S. national interests. The seemingly separate threads of human, robotic, civil, commercial and national security space activities are in fact deeply intertwined with each other, both politically and technically. The United States can best advance its national interests to a more integrated, strategic approach to its national security and civil space interests. International civil space cooperation, space commerce and international space security discussions could be used to reinforce each other in ways that would advance U.S. interests in the sustainability and security of all space activities.

It is well recognized that many of today's most important geopolitical challenges and opportunities lie in Asia. Asian space agencies have shown a common interest in lunar missions as a logical next step beyond low-Earth orbit. Such missions are seen as ambitious but achievable and thus more practical than missions to Mars

and more distant locations. They offer an opportunity for emerging and established space-faring countries to advance their capabilities without taking on the political risks of a competitive race with each other. A multinational program to explore the moon as a first step would be a symbolic and practical means of creating a broader international framework for space cooperation. At the same time, the geo political benefits of improving intra-Asian relations and U.S. engagement could support more ambitious space explorations than science alone might justify.

Europeans are also interested in being part of a return to the moon, and as recently as June of this year, Russia proposed a lunar program with the United States and publicly supported this position at international conferences. There are many geopolitical, scientific exploration, commercial and educational objectives that could be achieved at the moon, and in contrast, the case for a human mission to an asteroid is unpersuasive and unsupported by technical or international realities. We should be visionary but focused on practical actions.

The exploration and development of space is a reflection of the values we hold as a Nation. It is those values that are probably the most important to the long term for defining what NASA is and what space exploration is truly about. It is not just our DNA and our robots that go out there; it is our values. We are a Nation not defined by blood, tribe or religion but by conscious choice. Our choices are defined by adherence to the Constitution and the values of a tolerant culture, a democratic society and a market-driven economy.

In shaping the international environment for space activities, the United States should seek to build a more secure, stable and prosperous world in which our values are taken beyond the Earth. In doing so, we should also exercise some humility in face of the unknown. Did Thomas Jefferson know the ultimate economic return or impact from the investment in the Louisiana Purchase and the Lewis and Clark expedition? Did Teddy Roosevelt in sending the Great White Fleet and building the Panama Canal? Did Kennedy with Apollo? In their time, these projects were controversial and criticized in Congress but who today would say that they should not have been done? Through the long lens of history, we see that these efforts define us as a Nation, a Nation that pioneers the next frontier.

Let me conclude by observing that we are all in this together: the White House, Congress, U.S. government agencies, our international partners, Space Station, science community, universities, research centers and the many U.S. companies that create and operate our Nation's capability. Thus, I really commend and thank this Committee for holding this hearing today. Thank you for your attention, and I would be happy to answer any questions you might have.

[The prepared statement of Mr. Pace follows:]

Hearing of the House Committee on Science, Space, and Technology
Subcommittee on Space and Aeronautics Hearing

"NASA's Strategic Direction"

Wednesday, December 12, 2012 - 9:30 AM – RHOB 2318

Testimony of Dr. Scott Pace, Director, Space Policy Institute,
Elliott School of International Affairs, The George Washington University

Thank you, Mr. Chairman, for providing an opportunity to discuss the important topic of NASA's strategic direction. NASA has been asked to deal with several major changes in policy direction, program changes, and budget volatility in recent years. These changes have come about as a result of changes in Administration policy, increasingly constrained budgets, the completion of International Space Station construction, and the subsequent end of the Shuttle program.

What I hope to convey is that while NASA is facing very serious challenges, particularly in human space exploration, a way forward does exist to put the agency on a more stable and sustainable foundation that will advance US national interests. The technical and budgetary risks facing the agency are largely the more visible symptoms of deeper policy and management disconnects between the White House and Congress. These disconnects are not limited to NASA but can be found across all areas of space activity: civil, military, intelligence, and commercial. They affect US national security and foreign policy interests as well as scientific and economic objectives and reflect a lack of coherence in the oversight and execution of US space policy. Those disconnects are not inevitable and can be resolved by the White House and Congress, as well as NASA, and other agencies working together.

Challenges to US Leadership in Space

The loss of a second Space Shuttle, the *Columbia*, in 2003 resulted in the decision to retire the fleet after completion of the International Space Station. The *Columbia* Accident Investigation Board (CAIB) recommended that "because the Shuttle is now an aging system but still developmental in character, it is in the nation's interest to replace the Shuttle as soon as possible as the primary means for transporting humans to and from Earth orbit." The Board noted the failures in developing the National Aerospace Plane, the X-33, X-38, or any replacement for the aging Space Shuttle with the observation, "previous attempts to develop a replacement vehicle for the aging Shuttle represent a failure of national leadership."[1]

Plans to replace the Shuttle with a government-led system were disrupted by the 2010 decision to cancel NASA's Constellation program and shift to reliance on new

[1] *Columbia* Accident Investigation Board Final Report, Washington, D.C., August 26, 2003. Pg. 211. Accessed at http://caib.nasa.gov/news/report/pdf/vol1/chapters/chapter9.pdf

private providers for both cargo and crew launch services. The last Shuttle flight occurred in 2011 and the United States is now reliant on Russia for human access to space. While the Bush Administration contemplated a four-to five-year gap in US human access to space, strictly because of budget considerations, the current gap may now be more than six years. This is due to a change in strategic direction, i.e., NASA is no longer managing the development of human space transportation systems for access to low orbit while still providing the vast majority of funding for these systems. In August 2012, NASA announced the selection of three companies, SpaceX, Boeing, and Sierra Nevada as part of its Commercial Crew Integrated Capability Initiative (CCiCap). The firms are being funded to develop a privately owned and operated means of carrying crew to and from the International Space Station. NASA plans to bring only two companies to the "critical design review" stage before the construction of operational vehicles. If successful, the first flights by a single company could occur by 2017.[2]

In addition to the cost of paying Russia for crew transportation, US partners are concerned with relying on a single country for access to the International Space Station. Multiple Russian launch failures - Proton upper stage losses in August 2012 and December 2010, a Rockot loss in February 2011, Soyuz and Proton-M failures in August 2011, the Phobos-Grunt Mars mission loss on a Zenit in November 2011, and another Soyuz failure in December 2011 - have raised concerns that Russia's traditional strength in reliable launch vehicles may be fading. The successful berthing of the unmanned SpaceX Dragon cargo vehicle on the International Space Station in May 2012, and again in October, were welcome steps in restoring a limited US capability to send supplies to and bring back materials from the Station. These were only early steps, however, toward restoring a US human spaceflight capability.

In addition to disruptions in US human space flight, the United States was unable to make a long-term commitment to Europe for a joint, long-term program of robotic exploration of Mars, despite years of involvement in the planning process. This prompted the European Space Agency to invite Russia to be a full partner in the ExoMars program in October 2011 after discussions with the United States reached an impasse. Budget decsions have similarly prevented domestic production of Plutonium-238 after Russian supplies ran out. This nuclear fuel is critical to providing electrical power to missions traveling beyond Mars and long-term exploration of the planets. There is enough fuel for one more "flagship" mission but that will be the end of such missions without new supplies. Finally, budget uncertainty has caused delays in the construction of the next series of weather satellites and the United States may be facing a multiyear gap in meteorological data that will result in less accurate near-term weather predictions. All of these incidents

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[2] Dan Leone, "Boeing, SpaceX, and Sierra Nevada Stay in the Race for Commercial Crew," *Space News*, August 3, 2012. Accessed at http://www.spacenews.com/civil/120803-boeing-spacex-sierra-ccicap.html

create possible credibility issues and complications for US efforts to expand international cooperation in space.

NASA Human Space Flight Risks

The 2011 NASA strategic plan is a compilation of goals that reflect current NASA activities and aspirations that can be found in both congressional direction and national policy statements. The goals themselves are all worthwhile and attractive, but the document does not really contain a strategy for linking those goals to resources, setting priorities, or connecting agency goals to larger national interests that justify the allocation of public resources.

The NASA strategic plan does not drive the NASA budget requests or the allocation of relative emphasis to activities within the requests (e.g., exploration, science, aeronautics). As such, it is not surprising that there are numerous disconnects between stated policies, approved programs, and their actual funding. As is often stated, "budgets are policy" and NASA budgets are a more accurate reflection of *de facto* national policy than the NASA strategic plan. I will return to a discussion of recent NASA budgets in moment.

The NASA Office of the Inspector General has identified the future of human space flight as the top management and performance challenge for the agency. I believe this is correct as human space flight missions touch such a large proportion of the agency's budget, facilities, and workforce. The design, development, and operation of major space systems reflect the strategic engineering capacity of the United States. This capacity is most acutely represented by the technical and managerial challenges of developing new human-rated space systems.

There are debates over whether the "intellectual capital" for human space flight should be located primarily in the private sector and what skills should be maintained within NASA. Regardless of that debate, the ability of the United States to develop human-rated space systems resides with a trained and experienced workforce that must be planned for and maintained. Government and industry cannot have coherent workforce plans if they cannot define what skill mixes they need today or in the future. Skill mixes cannot be defined absent a clear understanding of government roles and responsibilities (e.g., what work is to be done in-house and what will be contracted out) and a stable set of mission requirements that are part of a larger architecture and exploration strategy. The lack of the latter elements contributes greatly to the risks identified by the NASA Inspector General.

In addition to the long-term problems with the lack of stable mission requirements and acceptable exploration architectures, the agency also faces near-term risks in human access to low Earth orbit. The two most important ones are the potential for loss of the International Space Station (ISS) and failure of one or more commercial crew funding recipients.

With the retirement of the Space Shuttle in 2011 and reliance on Russian Soyuz until 2017 at the earliest under current plans, access to and sustainment of ISS is a serious concern. In addition to the challenge of logistics, space debris presents a growing threat to the safety of astronauts aboard the station. NASA's 2011 Aerospace Safety Advisory Panel (ASAP) report indicated that there is an estimated 30 percent chance of a loss of mission for ISS, and noted that the safety of astronauts on the station is a designated "red category" concern that is not being addressed by NASA. The ASAP report also noted the recent Russian Progress failure, which impacted crew arrival and departure from ISS. The panel believes that continued reliance on a single, foreign system could result in the temporary or permanent abandonment of ISS prior to its end-of-life, resulting in an unplanned, potentially uncontrolled, deorbit significantly earlier than the 2020s.

Given the US investment in ISS, it is essential that a domestic system be developed as quickly as possible to provide redundant access to ISS. This leads to the second major risk, a technical or financial failure of commercial crew funding recipient. In August 2012, NASA entered into three Space Act Agreements (SAAs) with firms seeking to sell crew access to LEO and the ISS, including Boeing, SpaceX and Sierra Nevada Corporation. In doing so, NASA committed to spending $1.2 billion in development support over a 17-month period under these agreements before further down-selecting potential providers to a Federal Acquisition Regulation (FAR) contract that would enable human-rating certification.

Some of these recipients are new to development of human-rated space capabilities and may have limited access to capital outside of NASA's payments, should they need additional resources to meeting the periodic milestones agreed upon with NASA. In the event they are unable to meet milestones due to cost overruns or technical challenges, the firm(s) may require significant additional support payments to proceed – putting the US in the difficult position of letting a potential provider go under, or needing to secure additional budget. It is also possible that the firm(s) will not have systems that can be certified as human-rated after their development under SAAs. The US could be put in another difficult position of having to change its certification requirements or incurring additional costs to redesign the planned systems to meet NASA standards. In effect, given the high percentage of public funds involved, the Commercial Crew integrated Capability (CCiCap) Space Act Agreements are much like conventional NASA prime contracts. However, while NASA is reliant on their success, the agency lacks the oversight and enforcement mechanisms of normal prime contracts.

The Space Act Agreements do not provide clear mechanisms for NASA to impose specifications and ensure it is getting the product it wants for the public resources provided. In a more conventional "arms length" commercial arrangement, where NASA would not be providing front-end funding and would not be so dependent on the success of any given provider, this would not matter much. In the current environment in which there are no US alternatives for human access to orbit, this

dependence is a major risk. One of the most important observations from the CAIB for steps to take after the Space Shuttle was the following:

> "With the amount of risk inherent in the Space Shuttle, the first step should be to reach an agreement that the overriding mission of the replacement system is to move humans safely and reliably into and out of Earth orbit. "

Furthermore, the CAIB offered the admonition that:

> "The design of the system should give overriding priority to crew safety, rather than trade safety against other performance criteria, such as low cost and reusability, or against advanced space operation capabilities other than crew transfer."

By way of comparison, the Constellation Ares 1 program set a goal for probability of loss of crew in excess of 1:1000 with design estimates for reaching over 1:2800. In comparison the Space Shuttle's probability of loss has been estimated at less than 1:150. No other vehicles, including existing Evolved Expendable Launch Vehicles (EELV), are expected to exceed the 1:1000 standard. This is not to say they cannot do so in the future, but only after accumulating flight heritage comparable to the Shuttle solid rocket motors or the Russian Soyuz. In addition, liquid propulsion systems have more moving parts than solid propulsion systems and that complexity is an additional source of risk to be overcome.

These risks do not mean that the NASA is able to return to the Constellation solution of a government-designed, prime-contractor-built, Ares-1/Orion combination. That solution addressed LEO and lunar transportation in a tightly integrated way with the end of the Shuttle program. The conditions NASA faces today are different that those of 2008. Decisions made over the past four years have separated the LEO and beyond LEO transportation arenas. The systems being built for LEO transportation today share little direct commonality with beyond-LEO mission requirements. It does mean that NASA will likely have to become even more involved in the development of new crew transportation systems and will need additional contract mechanisms and stronger internal technical expertise to ensure the US regains independent human access to LEO.

The CAIB also commented on the need for stability of purpose in the development of new launch vehicles:

> "NASA plans to make continuing investments in 'next generation launch technology,' with the hope that those investments will enable a decision by the end of this decade on what that next generation launch vehicle should be. This is a worthy goal, and should be pursued. *The Board notes that this approach can only be successful: if it is sustained over the decade; if by the time a decision to develop a new vehicle is made there is a clearer idea of how the new space transportation system fits into the nation's overall plans for space;*

and if the U.S. government is willing at the time a development decision is made to commit the substantial resources required to implement it."

Recent years have instead seen great volatility in the resources for new vehicle development and exploration.

NASA Budget Instability

Large capital investments, high fixed costs, and specialized technical talent needs characterize major space business sectors, like space launch. This means that timing, phasing, and stability of funding is often just as important as the total level of funding. Unfortunately, recent years have been characterized by both lower funding AND greater volatility. Figure 1 shows NASA budget requests since the beginning of the current Administration. The FY 2010 budget was flat and characterized as a "placeholder" pending the Augustine Committee's review of plans for human space flight in 2009.[3]

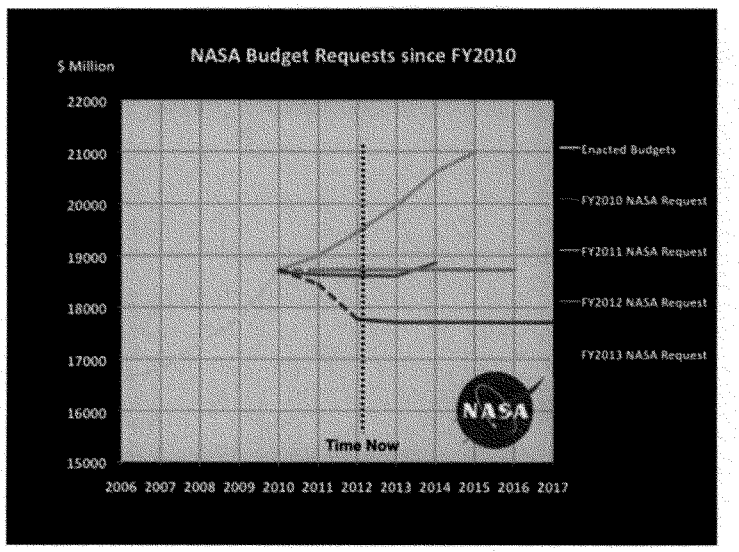

Figure 1 – NASA Budget Requests since FY 2010

The FY 2011 request released in February 2010 restored the NASA top-line to the level it had been during the previous Bush Administration – but with a significantly different portfolio, i.e., with more funds for commercial crew development,

[3] For the history of Presidential Budget Requests for NASA, see the NASA web site on budget information at http://www.nasa.gov/news/budget/index.html

technology and Earth science missions. The Obama Administration's budget proposal also cancelled the Constellation program to develop the Orion capsule, the Ares I launch vehicle, and the subsequent Ares V heavy lift vehicle. These capabilities were intended to support a human return to the Moon in the early 2020s and create the foundations for eventual human missions to Mars. The US Congress opposed the cancellations and a protracted political struggle ensued, which eventually resulted in the NASA Authorization Act of 2010. This Act did not provide significantly different total funding for NASA, but it did restore funds to develop the Orion and a shuttle-derived heavy lift vehicle called the Space Launch System. The lunar focus was replaced by what NASA termed a "capabilities-driven" evolution in which various missions would be defined as new capabilities were demonstrated.

The NASA budget profile again declined in the FY 2012 request. The budget was flat and at the level of the earlier FY 2010 "placeholder" proposal. The FY 2013 request declined again, with NASA now projected to be flat at even lower levels. Adding to the uncertainty, NASA and OMB did not even share the same projected spending levels in future years. In both the FY 2012 and FY 2013 budget requests, the phasing of reductions was different with near term declines and farther term increases contrasted with flat projections. Notwithstanding wry comments about "flat being the new up", such uncertainty and reductions in real purchasing power are more accurately described as "less is less." The phasing of reductions and differences over them makes it more difficult for NASA and industry managers to execute work efficiently as integrated work plans have to be changed and contracts renegotiated.

The impact of budget volatility has been especially severe in the case of human space exploration. Figure 2 shows reductions in NASA's exploration budget since FY 2009, the last budget of the previous Administration. Despite the volatility of the NASA top line, the steady trend in exploration has been down. For FY 2011, 2012, and 2013, the lines in Figure 2 assume that 100% of the space technology budget line contributes to exploration. If the actual percentage is less, say 50%, then the decline is even more dramatic. NASA is still a large and capable agency, but an increasing proportion of its resources are not going to human space exploration.

NASA's budget request for 2013, $17.7 billion, is virtually the same as it was for 2009. The Augustine Committee's recommendation to increased NASA's total budget by $3 billion per year was clearly not heeded. An obvious question to ask is whether any other budgetary outcome would be affordable. NASA's budget is less than 0.5 percent of the entire Federal budget. From that perspective, the NASA budget is not a question of affordability but of priorities.

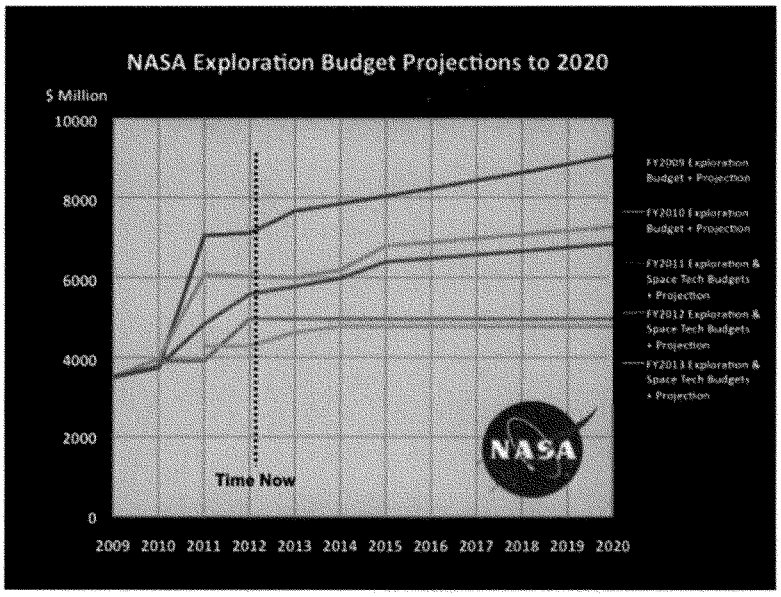

Figure 2 – NASA Exploration Budget Projections

The NASA budget is a political choice – it is a reflection of what the United States values as a society. Put another way, the Obama Administration's stimulus program was greater than NASA's budget from 1958 to 2008 – in constant dollar terms. The United States sent humans to the Moon, built and operated a Space Shuttle fleet for 30 years, explored the solar system, and contributed its share of the International Space Station for less than the cost American Recovery and Reinvestment Act of 2009.[4] The significance of such a comparison is not that space is inexpensive. Rather, it is that in today's environment with massive debt and an anemic economic recovery, sustaining discretionary expenditure for civil space exploration will be especially challenging unless there is a clearer rationale linking such efforts to broader national interests that can be supported in a bipartisan manner over many years. Such a rational is possible, as will be discussed next.

National Space Policy and Exploration

The 2010 US National Space Policy is a comprehensive document that addresses the full range of US interests in space. The policy continues many long-standing

[4] On January 26, 2009, the Congressional Budget Office estimated the cost of the American Reinvestment and Recovery Act of 2009 as $816 billon for 2009-2019. Total NASA spending for 1958-2008 was about $800 billion in 2008 dollars. See http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/99xx/doc9968/hr1.pdf

principles, such as the right of all nations to engage in the peaceful uses of outer space, recognition of the inherent right of self-defense, and that purposeful interference with space systems is an infringement of a nation's rights. It states that the United States "recognizes the need for stability in the space environment" and that we will pursue "bilateral and multilateral transparency and confidence building measures to encourage responsible actions in space."

The general coherence on the national security and foreign policy side is not matched in the section dealing with civil space exploration. The policy says that the NASA Administrator shall "set far-reaching exploration milestones. By 2025, begin crewed missions beyond the moon, including sending humans to an asteroid." Unlike the carefully crafted text elsewhere in the policy, this section appears to have been directly taken from an April 15, 2010 speech by President Obama at the Kennedy Space Center in Florida. Subsequent technical work has shown that there are few, if any, scientifically attractive asteroids that can be reached on this schedule. Even worse, the international space community, which had been shifting attention to the Moon in anticipation of that being the next US focus of exploration beyond low Earth orbit, felt blindsided. Countries in Asia, such as Japan, India, China and South Korea saw the Moon as a challenging but feasible destination for robotic exploration and a practical focus for human space exploration. The proposed asteroid mission is not, and was (perhaps unintentionally) taken as a sign that the United States was not interested in broad international cooperation, but would focus on only the most capable countries, such as Russia and perhaps Europe.

The perception that the next steps in human space exploration would be too difficult to allow meaningful participation by most spacefaring countries undercut international support for human space exploration more generally. The lack of US support for a program to return to the Moon made it difficult for advocates of human space exploration in Europe, Japan, India, and elsewhere to gain funding for any efforts beyond the International Space Station (ISS). The ISS is itself under budget pressure to justify its construction and on-going operations costs, a task that has been more difficult by the lack of a clear direction for human space exploration beyond low Earth orbit. The lack of international leadership by the United States may, however, provide an opportunity for rising spacefaring countries such as China to play a greater role in the future. If China is able to offer pragmatic opportunities for space cooperation on its own space station or as part of efforts to send humans to the Moon, other countries will likely it attractive to forge closer relationships with China. A shift in international space influence away from the United States and toward China would have the potential to impact a wide range of US national security and foreign policy interests in space.

A US-led effort to develop an international lunar base was and still can be a goal to which all spacefaring nations could contribute. In addition, new information from lunar robotic missions have strengthened scientific motivations explore the Moon further. It should be noted that as recently as June of this year, Russia proposed an international lunar program with the United States and publicly supported this

position at international conferences. There are many geopolitical, scientific, exploration, commercial, and educational objectives that could be achieved at the Moon. To forego the opportunity for international collaboration to explore the Moon in favor of an asteroid mission, where there is little interest and no compelling objectives for a human mission, is a policy that is unsupported by technical or international realities.

Strategic Approaches to Human Space Exploration

Unmanned space exploration efforts in planetary science, astrophysics, and heliophysics are under great stress due to budget overruns and schedule delays from large "flagship-class" efforts (e.g., the Curiosity Mars Science Laboratory and James Webb Space Telescope). This has resulted in cancellation of smaller, lower priority missions and a reduction in flight opportunities for researchers not already on the largest programs. The problems faced by these science programs represent programmatic, not existential, questions. There is no debate in the United States about whether to have a space science program, but rather what level of effort is affordable and executable.

In contrast, there is an on-going debate over whether and what kind of human space exploration effort the United States should have. While many supporters of human space flight see such efforts as "inevitable" or "part of our destiny," those views are not widely enough held to ensure stable political support. At the same time, there is a level of support for the symbolism of human space flight and a sense that it may have longer-term practical value that make US political leaders reluctant to cancel such efforts or to be seen as supporting such an action. Human spaceflight (if not pure exploration) may one day become a self-sustaining commercial activity but that day has not yet come.

There are many diverse reasons individuals may have for supporting human space flight along with many different activities that could constitute an on-going human space flight effort, e.g., space tourism, landing on Mars, exploiting space resources, etc. Aside from an Apollo-like political crisis, which seems unlikely to reoccur, there are three major alternative strategic approaches the United States might take toward human space exploration: Capability-driven, Question-driven, and Geopolitically-driven.

Capability-driven

The current US approach to human space exploration is officially described as "capability driven":

> NASA's human space exploration strategy focuses on capabilities that enable exploration of multiple destinations. This capability-driven approach is based on a set of core evolving capabilities that can be leveraged or reused, instead of specialized, destination-specific hardware. This approach is

> designed to be robust, affordable, sustainable, and flexible, preparing NASA to explore a range of destinations and enabling increasingly complex missions.[5]

This approach does not focus on a specific destination, question, or purpose for human space flight, but rather seeks to keep a range of options open while deferring decisions on specific architectures and rationales. In a budget constrained environment without any specific political or economic rationale, such an approach avoids both the need to make a decision to cancel human space flight, or, if it is not to be cancelled, the need to specify what it is that human space flight should accomplish.

This is not the first time the United States has taken this approach. In the aftermath of the Apollo program, the Nixon Administration did not want to cancel human space flight but neither did it want to continue the costs and risk of human missions to the Moon and eventually Mars. In 1970, while the lunar landings were still underway, President Nixon said:

> We must realize that space activities will be a part of our lives for the rest of time. We must think of them as part of a continuing process-one which will go on day in and day out, year in and year out -- and not as a series of separate leaps, each requiring a massive concentration of energy and will and accomplished on a crash timetable.... We must also realize that space expenditures must take their proper place within a rigorous system of national priorities.[6]

The 1972 decision to build the Space Shuttle was explained by NASA Administrator James Fletcher in a similar, low-key fashion:

> There are four main reasons why the Space Shuttle is important and is the right step in manned space flight and the US space program.
> 1. The Shuttle is the only meaningful new manned space program which can be accomplished on a modest budget;
> 2. It is needed to make space operations less complex and less costly;
> 3. It is needed to do useful things, and
> 4. It will encourage greater international participation in space flight.[7]

In essence, NASA would develop a human space flight capability that would continue to enable the United States to send humans into space, be more affordable, and

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[5] NASA, "Voyages: Charting the Course for Sustainable Human Space Exploration," Washington, D.C., June 7, 2012. Accessed at http://www.nasa.gov/exploration/whyweexplore/voyages-report.html

[6] T.A. Heppenheimer, *The Space Shuttle Decision*, NASA-SP-4221, Washington, D.C., 1999. See Chapter 9, "Nixon's Decision." Accessed at http://history.nasa.gov/SP-4221/ch9.htm

[7] NASA, Statement by Dr. James C. Fletcher, NASA Administrator, January 5, 1972. Accessed at http://history.nasa.gov/stsnixon.htm

hopefully accomplish useful tasks still to be determined. The Obama Administration's current approach is arguably similar to that taken by the Nixon Administration in the early 1970s.

Question-driven

An alternative strategic approach is to take an intentionally question-driven approach and pose questions or grand challenges to be addressed by human space exploration efforts – or at least those efforts that rely on public resources. In this approach, a program of human space exploration is more than a series of spectacular engineering demonstrations – as in the case of Apollo – but a means of answering questions important to society.

After gaining foundational capabilities like space transportation, communications, navigation, and power, an exploration program could look to ways to use in-situ resources, create new resupply methods, and commercial partnerships. This could help move debates beyond "robots versus humans" or "Moon versus Mars" or "Science versus Exploration" to a more question-driven, mission-focused series of decisions.

Just as the *Challenger* accident led to questioning whether human life should be placed at risk in launching satellites that could be carried by an unmanned rocket, so the *Columbia* accident led to asking for what purposes, if any, was risking human life worthwhile. The Columbia Accident Investigation Board concluded that the nation should continue a program of human space flight, eventually moving beyond Earth orbit. Although not stated explicitly, the implication was that if the nation were to continue to place human life at risk, staying in low Earth orbit was an insufficient goal to justify such risks.

For those who believe that human expansion into the solar system should be an important part of what the United States does as a nation, abandoning human space flight completely or even staying in low Earth orbit would be unacceptable. However, there are many who do not share the same feeling about the priority of human space flight to the nation, and it would be realistic to squarely acknowledge that uncertainty. The original decision to go to the Moon was an answer to President Kennedy's question on whether the United States had a chance of surpassing the Soviet Union in any area of space achievement. The change in payload policy after *Challenger* was an answer to the question of whether it was justifiable to risk humans for satellite deployments. After *Columbia*, the CAIB recommendation to eventually go beyond low Earth orbit was an answer to the question of whether humans should be in space at all.

Today, what is the question for which the human exploration of space is the answer? Such a question could be, "Does humanity have a future beyond the Earth?" Either a yes or a no answer would have profound implications. Addressing this question quickly leads to two sub-questions: can humans "live off the land" away from Earth,

and is there any economic justification for human activities off the Earth?[8] If the answer to both questions is yes, then there will be space settlements. If the answer to both questions is no, then space is akin to Mount Everest – a place where explorers and tourists might visit but of no greater significance. If humans can live off-planet, but there is nothing economically useful to do, then lunar and Martian outposts will, at best, be similar to those found in Antarctica. If humans cannot live off-planet, but there is some useful economic activity to perform, then those outposts become like remote oil platforms. Each of these scenarios represents a radically different human future in space and while individuals might have beliefs or hopes for one of them, it is unknown which answer will turn out to be true. That is, the answer can only be found by actual experience and new information.

The science community has used the productive practice of posing simple but profound questions to shape and guide the implementation of research strategies. To ask "is there life elsewhere in the universe?" leads to questions of whether there is life elsewhere in the solar system, the search for water on Mars, and missions exploring for water and signs of life in particular locations. These questions shape the design and execution of space missions. The human space flight community could benefit from adopting similar practices to design and prioritize its missions. In this vein, consideration should be given to a routine survey that assesses progress in (or lack of) human spaceflight and reviews priorities on a ten year time scale as done for scientific fields. For example, priority could be given to answering such questions as:

- Can humans operate effectively away from Earth for long periods of time?
- Can we utilize local resources to lower reliance on materials from Earth?
- Are self-sustaining commercial activities (requiring direct or close human involvement) in space possible?

Such routine reviews could also improve the stability of human spaceflight efforts across Administration transitions. If the United States could shift away from existential debates on whether or not to have a human space exploration effort, it could use open, enduring questions to guide programmatic decisions for an affordable and effective human spaceflight effort.

Geopolitically-driven

The third strategic approach is the most historically common for the United States, a human space exploration effort driven by geopolitical interests and objectives. The United States undertook the Apollo program in the 1960s to beat the Soviet Union to the Moon as part of a global competition for Cold War prestige. The Apollo- Soyuz program symbolized a brief period of détente in the 1970s. The Space Station program was established in the 1980s, in part, to bring the developing space capabilities of Europe and Japan closer to the United States and to strengthen anti-Soviet alliances. Russia was invited to join a restructured International Space

[8] Harry L. Shipman, *Humans in Space: 21st Century Frontiers*, New York: Plenum Press, 1989.

Station in the 1990s to symbolize a new post-Cold War, post-Soviet relationship with Russia. What might be the geopolitical rationale for the next steps in human space exploration?

It is well recognized that many of today's most important geopolitical challenges and opportunities lie in Asia. States under UN sanction, for example, Iran and North Korea, are seeking to develop ICBM capabilities under the guise of space launch programs. China, India, and South Korea are demonstrating increasingly sophisticated space capabilities that serve both civil and military needs. Examples of these capabilities include satellite communications, environmental monitoring, space-based navigation, and scientific research. Unlike Europe, there are no established frameworks for peaceful space cooperation across Asia. In fact, the region can be characterized as containing several "hostile dyads" such as India-China, North Korea-South Korea, and China and its neighbors around the South China Sea.[9] The United States has better relations with almost all of these countries than many of them have with each other.

Asian space agencies have shown a common interest in lunar missions as the logical next step beyond low Earth orbit. Such missions are seen as ambitious but achievable and thus more practical than missions to Mars and more distant locations. They offer an opportunity for emerging and established spacefaring countries to advance their capabilities without taking on the political risks of a competitive race with each other. A multinational program to explore the Moon, as a first step, would be a symbolic and practical means of creating a broader international framework for space cooperation. At the same time, the geopolitical benefits of improving intra-Asian relations and US engagement could support more ambitious space exploration efforts than science alone might justify.

Integrating National Interests in Space

From the beginning of the Space Age, space activities have been "tools" of both hard and soft power for participating nations. Hard power is represented by alliances, military capabilities, and economic strength that can compel and pay others to do what we desire. Cultural, diplomatic, and institutional forces are aspects of soft power by which we are able to persuade others to do what we desire. In seeking to advance international space security interests, the soft-power influence brought about by leadership in civil and commercial space activities must be considered. Countries lacking a stake in stable, peaceful space environment are unlikely to be supportive of US and allied space security concerns. It is not that those countries will be opposed to security concerns, but that they will not see the relevance to their own needs and interests. As an example, international interest in mitigating orbital debris has grown as more countries have realized the threat such debris can pose to space systems they rely on and to their citizens working in space.

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[9] James Clay Moltz, *Asia's Space Race*, New York: Columbia University Press, 2011.

A broad program of human space exploration would help garner support for other international objectives in support of US interests, both on Earth and in space. Organizing such a program will not be easy – not the least because of errors and confusion in US space policy statements, strategies, and programs. US global influence has been diminished by removal of the Moon as a focus for near-term human space exploration efforts, a failure to cooperate with Europe on the next stage of robotic missions to Mars, and limitations in space object tracking and notification capabilities that would reduce the risk from orbital debris for all space users.

Now that construction of the International Space Station has been completed, the priority of all the partners is rightly on utilization. Whether the Station is sustained beyond 2020 will likely depend on both the cost of continuing operations and research results. If costs are high compared to demonstrated and likely results, the partners could decide to end the program. If operating costs are affordable and research results sufficiently impressive, then the program may continue for many years. In this way, the Station will be less of a political statement in the future than it will be a major scientific facility to be judged on the basis of its productivity and cost. If the current international partners do not see the ISS as a success, it is difficult to imagine international support for new human space exploration efforts.

Since major space projects take so long to implement, it is appropriate to be working now on what should come after the Station – even if the Station's end date is not certain. It is generally assumed that human space exploration beyond Earth orbit will not be done by individual nations (save perhaps China) so it makes sense to ask potential international partners what they are capable of and interested in doing. In this regard, human missions to asteroids or Mars are beyond the practical capabilities of almost all potential partners but can still serve as long-term goals.

Despite the spectacular success of the August 2012 landing of Curiosity on Mars, the future of unmanned Mars exploration remains highly volatile. No clear path forward exists with respect to returning samples from Mars or what flagship-class mission will come next. In the longer term, there is great uncertainty that robotic Mars exploration can continue to be productive and sustainable separate from human space exploration efforts. For example, little impetus exists to develop ever more capable entry-descent-landing (EDL) techniques without the goal of eventually being able to land humans on the Martian surface. At the same time, robotic precursors are needed for any human space explorations beyond Earth orbit. A closer integration of human and robotic missions should be done to benefit both science and exploration. Even if human missions to Mars come decades after a human return to the Moon, it will still be beneficial for robotic precursor missions and human exploration plans to be closely aligned with each other. These efforts will be drawing on similar technical capabilities and, for government-funded missions, similar sources of budgetary and political support.

If there is to be a serious effort at engaging international partners, a lunar-based architecture is most likely to emerge as the next focus of human space exploration. In addition, a lunar focus would provide practical opportunities for using private sector initiative, e.g., cargo delivery to the lunar surface. This could be done in a manner similar to International Space Station cargo delivery, but it would represent at least an order of magnitude greater addressable market even for an initial lunar base with the same number of crewmen as the Station.[10]

Potential international partners have been confused by a lack of clear US space goals and priorities, and especially by the cancellation of plans to return to the Moon without establishing a viable alternative. Looking beyond the International Space Station, they have not seen opportunities for engagement other than in individual scientific collaborations. As one European space agency head put it, "there is lots of cooperation with Europeans, just not with Europe."[11] The International Space Station is the only example of strategic, as opposed to opportunistic, cooperation with Europe at present. It should go without saying that the United States should be in the position of advocating and leading new strategic initiatives, rather than merely responding to those of others.

Human space exploration is at a crucial transition point with the end of the Space Shuttle program and the lack of clear objectives beyond the International Space Station. At the same time, new space actors are present who lack the operational experience of major space projects with the United States. However, these actors have the potential to affect the sustainability, safety, and security of the space environment and thus impact US interests in space. The seemingly separate threads of human, robotic, civil, commercial, and national security space activities are in fact deeply intertwined with each other, both politically and technically. The United States can best advance its national interests through a more integrated strategic approach to its national security and civil space interests. International civil space cooperation, space commerce, and international space security discussions could be used to reinforce each other in ways that would advance US interests in the sustainability and security of all space activities.

Recommendations

US national space policy should be updated to make a more explicit recognition of the need for international partners in a long-range vision of human space exploration. In particular, current language in the National Space Policy that directs NASA to send human to asteroid by or after 2025 and to orbit Mars by the mid-2030s should be deleted. Language from the NASA Authorization Act of 2010 could

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[10] Michael D. Griffin, "Enabling Complementary Commercial and Government Enterprises in Space," IAC-11.E3.4.6, paper presented to the 62rd International Astronautical Congress, Cape Town, South Africa, October 6, 2011.

[11] Personal communication

be adopted instead and thus bring White House and Congressional policy directions into closer alignment. Example text could be:

> NASA's human space flight and exploration efforts should enable the expansion of permanent human presence beyond low-Earth orbit and to do so, where practical, with international partners.

I would also recommend replacing the current capability-driven approach with one that is more geopolitical and based on an international accepted lunar architecture. If that is too politically difficult to achieve in the near term, then the NASA Authorization Act has alternative language that take a more question-driven approach:

> NASA should sustain the capability for long-duration presence in low-Earth orbit, initially through continuation of the International Space Station; determine if humans can live in an extended manner in space with decreasing reliance on Earth; identify means for meeting potential cataclysmic threats; explore the viability of and lay the foundation for sustainable economic activities in space; advance our knowledge of the universe; support United States national and economic security and the United States global competitive posture, and inspire young people in their educational pursuits.

Constraints on government budgets are such that private sector initiative, partnerships, and competition will be of increasing importance to many (but not all) space activities. In recognition of this fact, international discussions of space cooperation should also include measures to create greater stability, in both regulatory and policy arenas, in order to provide greater encouragement of private space activities. Legal support for the private utilization and exploitation of non-terrestrial materials and functional property rights should be part of incentives for space commerce and development.

An important element in getting the right balance between public and private sector roles and responsibilities is the use of clear definitions. In recent years, there are has been considerable confusion in what space activities are truly commercial and which are merely privatized government activities or contracting with different terminology. Past national space policy statements, such as the 1991 Commercial Space Guidelines, already provide clearer definitions, such as:

> Commercial space sector activities are ones in which private capital is at risk; there are existing, or potential, nongovernmental customers for the activity; the commercial market ultimately determines the viability of the activity;

> and primary responsibility and management initiative for the activity resides with the private sector.[12]

Given clearer policy priorities and closer agreement between the White House and Congress, NASA would be in a better position to implement its assigned missions and undertake necessary internal reforms. Attachment 1 contains a high-level summary of recommended NASA management priorities, covering science and exploration, and ranging from flight safety to congressional relations. NASA is already implementing many of them today but others – particularly in management reform – are impossible without the high-level policy and architecture decisions I have described.

Underlying all recommendations for management reforms is the need to ensure that space policies, programs, and budgets are in alignment, since to do otherwise is to invite failure. The first consideration for any policy choice and implementing architecture is that it be funded – with clear priorities on which schedules and performance goals will be relaxed if resources are not forthcoming. To do otherwise is to imperil mission success and it would be more realistic to do and say nothing.

Our Nation's space program needs clear, decisive, and steadfast leadership. We have enjoyed a half-century of leadership in space, but now that leadership is eroding despite the hard work of our industry and government personnel. Yes, more money would be useful, but steadiness of purpose, coherence, and bipartisan support are even more important.

Let me conclude by observing that we are all in this together – the White House and Congress, US government agencies, our international partners on the Space Station, the science community at universities and research institutes, and the many US companies that create and operate our nation's space capabilities.

Thank you for your attention. I would be happy to answer any questions you might have.

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[12] The White House, Office of the Press Secretary, U.S. Commercial Space Policy Guidelines, NSPD-3, February 11, 1991. Accessed at http://www.au.af.mil/au/awc/awcgate/nspd3.htm

Attachment 1

Recommended NASA Management Priorities

1. Fly Safely

   The safety of NASA astronauts, civil service work force, contractors, and the public are of paramount importance. Performing agency missions requires taking calculated risks, so while the agency must operate in dangerous environments, it should seek to do so safely to the maximum practicable extent. Consistent with the recommendations of the *Columbia* Accident Investigation Board, seek to ensure major improvements in flight crew safety.

2. Management Reform
   a. Clearly define agency missions consistent with Presidential direction and Congressional authorization.
   b. Implement "best practice" governance both internal to the agency and in relationship to key White House offices (e.g., OMB, NSC, and OSTP). Seek to ensure that NASA management has the necessary flexibility and accountability to execute assigned missions.
   c. Provide clear guidance on the appropriate roles for government and industry in the conduct of NASA missions across the diverse fields of research, development, and operations. Ensure NASA retains sufficient expertise to fulfill necessary oversight and leadership roles.
   d. Align agency capabilities, i.e., human capital and institutional assets, to successfully execute NASA mission in the short and long-term. This includes shaping workforce skill mixes and shedding or adding facilities as needed to be more efficient and effective.
   e. Plan and program multi-year budgets with known confidence levels to implement national policy and legislative direction. Identify areas of disconnect between available resources and goals and prioritize alternatives for their resolution. This may require additional resources, changes in performance objectives and schedule, or acceptance of greater risk.

3. Congressional Relations

   Strengthen broad bipartisan support for strong and sustainable NASA programs of science and exploration. In particular, seek to create a greater alignment between the policy objectives of the White House and Congress and increase trust in the agency to enable greater flexibility in program design, development, and operations.

4. International Relations

   Rebuild broad international support for US leadership in human and robotic space exploration. In particular, work to define a common international approach to human space exploration beyond low Earth orbit. This approach should enable the practical participation of existing International Space

Station partners and other countries, consistent with US national security and foreign policy interests.

5. Science
   Adhere to the science priorities as contained in the decadal surveys by the National Academies. US agencies, industries, and universities should be encouraged and supported to pursue balanced portfolio of high quality science and technology development in the US portion of the International Space Station.

6. Space Transportation
   Restore the ability of the United States to provide crew access to low Earth orbit. Ensure a sustainable mix of public and space transportation is available to provide assured access to space. NASA and the Department of Defense will cooperate on common approach to sustaining the US space launch industrial base.

7. Space Commerce
   Consistent with scientific and exploration mission objectives, seek to encourage the growth and commercial competitiveness of US industry. NASA can and should take on diverse role in support of space commerce, e.g., through R&D, the reduction of technical risk, being a first or on-going customer for routine goods and services, and facilitating appropriate regulatory oversight by other federal agencies. NASA should not preclude or deter commercial space activities except for reasons of national security or public safety.

8. Human Space Exploration beyond low Earth Orbit
   Consistent with Congressional direction, NASA's human space flight and exploration efforts should enable the expansion of permanent human presence beyond low-Earth orbit and to do so, where practical, with international partners. NASA should sustain the capability for long-duration presence in low-Earth orbit, initially through continuation of the International Space Station; determine if humans can live in an extended manner in space with decreasing reliance on Earth; identify means for meeting potential cataclysmic threats; explore the viability of and lay the foundation for sustainable economic activities in space; advance our knowledge of the universe; support United States national and economic security and the United States global competitive posture, and inspire young people in their educational pursuits.

Scott Pace

Dr. Scott Pace is the Director of the Space Policy Institute and a Professor of the Practice in International Affairs at George Washington University's Elliott School of International Affairs. His research interests include civil, commercial, and national security space policy, and the management of technical innovation. From 2005-2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA.

Prior to NASA, Dr. Pace was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy (OSTP). From 1993-2000, Dr. Pace worked for the RAND Corporation's Science and Technology Policy Institute (STPI). From 1990 to 1993, Dr. Pace served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. He received a Bachelor of Science degree in Physics from Harvey Mudd College in 1980; Masters degrees in Aeronautics & Astronautics and Technology & Policy from the Massachusetts Institute of Technology in 1982; and a Doctorate in Policy Analysis from the RAND Graduate School in 1989.

Dr. Pace received the NASA Outstanding Leadership Medal in 2008, the US Department of State's Group Superior Honor Award, *GPS Interagency Team*, in 2005, and the NASA Group Achievement Award, *Columbia Accident Rapid Reaction Team*, in 2004. He has been a member of the US Delegation to the World Radiocommunication Conferences in 1997, 2000, 2003, and 2007. He was also a member of the US Delegation to the Asia-Pacific Economic Cooperation Telecommunications Working Group, 1997-2000. He is a past member of the Earth Studies Committee, Space Studies Board, National Research Council and the Commercial Activities Subcommittee, NASA Advisory Council. Dr. Pace is a currently a member of the Board of Trustees, Universities Space Research Association, a Corresponding Member of the International Academy of Astronautics, and a member of the Board of Governors of the National Space Society.

Chairman HALL. And we thank you, Dr. Pace. I thank all of you for your testimony, and I remind Members that Committee rules limit questioning to five minutes for each of us. I will open the round of questions and recognize myself for five minutes.

As I sit here, I don't ever like to say it is my last day. This is the last day for this week, at least. I don't like anything last. I don't even like for them to call an airport a terminal. That doesn't sound good to me at my age. I was just thinking of the really wonderful testimony all of you all have given and the time that it took you to gather to have that and then to gather up on it and then deliver it to us. It is really great of you and generous of you.

I go back and I glean from each of you that there is need for more funds. The Norm Augustine committee recommended, if you remember, Bob, $3 billion additional for NASA per year. That wouldn't have even brought us up to one percent of the overall budget. That is a shame. Three Presidents turned their backs on us on that when we asked them for that additional money. Things could be different today, I think, had we been able to edge that into the budget for NASA. We needed it.

Bob, you suggested several modifications, and Administrator Blakey, thank you. I have a question or so.

General, let me ask you, General Sega, what reaction, if any, has your Committee received from the Administration with regard to the recommendations you lay out? And I liked your recommendations. Specifically, you cite a need for a new national consensus for NASA's future. Does the Administration agree with such a consensus is needed, or can you answer that?

General SEGA. Mr. Chairman, the report was briefed last week to a NASA administrator and staff, and I believe it was well received, and we have not briefed any other elements of the Administration besides NASA.

Chairman HALL. Okay. Let me ask Dr. Pace——

General SEGA. Excuse me. I stand corrected there. We also have briefed Dr. Holdren at OSTP.

Chairman HALL. Okay. What was their reaction? They kind of speak for the President, I think, sometimes.

General SEGA. Correct, and they were mostly in a listening mode, and again, they hadn't gone through it in detail, but we did present our recommendations and so we would await their reaction.

Chairman HALL. Okay. Dr. Pace, your testimony points out how potential international partners have been confused by lack of clear space goals and priorities and especially by the cancellation of plans to return to the moon without a viable alternative. Why don't you elaborate on why the moon is a more appropriate step for our international partners than an asteroid or Mars? To me, the Space Station is number one. It is so important. If we can't do that, we can't do anything, and we would absolutely lose our international partners. That is the next thing that everybody points out. But how to keep them? We need more money. I think it is too late to ask for that additional billion or that that would help us, the $3 billion that was suggested by the man that has led every study I guess that has ever been made for this Committee. Does the Administration—you will know whether or not the consensus is needed. Does NASA believe that a consensus is needed?

Dr. PACE. Sir, would you like me to answer the international question or the NASA question?

Chairman HALL. The NASA question.

Dr. PACE. Well, I think that not being with NASA, of course, today, as I look at NASA from the outside, I think that they in fact do feel frustrated by the disconnects between the White House and Congress. They of course would like to have some clearer direction and support. But I think that if you ask them as representatives of the Administration, I think they would say well, we have a direction, we have a policy, and we are trying to execute that policy as best we know how. The problem is I think, particularly in civil space exploration, is disconnected from technical and political realities. I completely agree with you that the Space Station is the most vital immediate thing we have to be focused on. But then we have to be looking, what comes after the Space Station, and this is where I think our international partners feel a bit left out because Mars and asteroids are extremely challenging. They are extremely challenging for us. And as a result, when they look at themselves and they look at their own agencies, they don't see a way for meaningful international cooperation with us on those programs, certainly in the manned side of things. And therefore they are left really without a way forward to work with us.

I think that hurts us because the consensus I think in the U.S. community is that international cooperation is essential to any exploration beyond low-Earth orbit. Nobody thinks we are going to repeat the Apollo program going there by ourselves, and so it makes sense to ask what could our international partners do, what are they capable of doing, and we really haven't provided a hook for our partners in the current policy. That leads to the disconnect with larger geopolitical interests which then leads to the sense of drift that I think NASA feels.

Chairman HALL. We know we can go to the moon. How do you feel about putting major emphasis on the Space Station and not forgetting that we want to go to Mars or that we intend to go to Mars and keep an ear open to that but not to be asking for vast, expensive and great amounts of money that it is going to take to do that until we perfect reaching our own Space Station and claiming back our Space Station that we are almost turning our back on by having to beg the Russians for a trip up there and back?

Dr. PACE. No, I think that if one does not support the Space Station, anything else is kind of meaningless. In the aftermath of the Columbia accident, we had very serious conversations with our international partners as to whether or not they wanted to stop and just simply call it a day, and they were very, very clear that we had to continue with the Space Station, they had made these commitments to it, it was not practical to talk about other international cooperation if in fact we failed at the station. So I think the number one issue and I think also as part of my written testimony, utilization of the Space Station is the near-term issue. Ensuring access to the station with high reliability is the top issue for ensuring utilization.

One of the concerns—this is maybe a whole separate discussion—is on the sustainability of the station with the rather fragile logistics support that we have right now. The new commercial cargo ca-

pabilities that are coming online are extremely critical, extremely necessary. If there is any faltering or delays in that, we are going to be looking at the potential for having to maybe reduce the manning on the Space Station, and if that happens, then we are going to be looking at our utilization going down.

Chairman HALL. I thank you, sir.

My time has expired. At this time I recognize Mrs. Edwards for her—Ms. Johnson for her five minutes.

Ms. JOHNSON. Thank you very much, and let me thank each of the witnesses for extraordinary testimony.

I am sitting here in sort of a state of frustration. I think that this Committee is expected to be a visionary committee and also I feel very strongly that our future in research, development and innovation rests with what we recommend or what we do, and our opinion. We are not appropriators on this Committee but we are very mindful of the fact that we have very little money. But I still think that with the help of experts, we can at least lay out what we consider the vision for our country's research and innovation through space research, and then allow the Administration or the appropriators to determine what we can and cannot do. I think that currently there is so much frustration as to where NASA is concerned that they really don't know what is coming next.

Just looking at what has happened so far in space exploration research, it is clear to me that where we are now came almost exclusively but certainly from space exploration research. I believe that to stop and decide we can't afford it is simply saying to our future, we won't be there. We won't be there for our young people, we won't be there for the inspiration, we are just going to take a backseat and watch the rest of the world. We won't need to educate our young people if we are not going to give some opportunity for participation.

So I guess my question is, how would you help us come to a real recommendation that speaks to what we consider to be the needs in the future rather than just the money? We know it costs, but we have got to make some real serious decisions, and I don't think we have half-step it. We have got to decide that we are going to invest in our future and eliminate the need for food stamps or whether we are going to continue to pay for more and more and more food stamps. And so I am very, very concerned because I know that we are very sensitive to the cost on this Committee, and we should be, but we really are not the appropriators; we are the visionaries. We are the people who are supposed to be looking to see what our Nation needs to keep pace and to continue to be leaders. So I need to know if you would give me some of your opinions on where you really think we ought to be if we were brave enough to say this is what we need, take it or leave it, Mr. President. Anybody? Mr. Walker, why don't you start?

Mr. WALKER. Well, I agree absolutely with your premise, and I think that the role that the government has to play in NASA is to assure that its missions are future-oriented, and I think we have spent an awful lot of money in recent years on essentially operational issues and so on. What this Committee could do is give us a sense of direction. I mean, do we go back to Mars, do we do some of these kinds of things, but in order to do that, then you have to

commit yourself to some high-risk technologies because in my view, it is extremely important that you, for instance, reduce the time that it takes to go to Mars if you are going to do it. The only way it is politically viable is if you can go there in weeks rather than years, and the fact is, we could develop technologies along those lines but it is going to take the Committee's decision in your authorization process to give NASA those kinds of instructions to move it forward. And what I was suggesting in my testimony is that there are ways to reach out for some of the other things that you are doing for money.

Since I left Congress, I have been involved with an FFRDC. You will notice that in the Aldridge Commission report, they recommended at least some of the NASA centers move to that kind of model. Why? Well, because at that point you can have both a government funding stream going into the operation as well as outside money coming in to the operation to do other things, and that allows you then to have some streams of money that do not necessarily depend upon the appropriations process. I don't know if that is exactly the right model for NASA but it seems to me that this Committee working could come up with something along those lines. That allows you then to look forward as well as find the resources necessary, not wholly government resources, and that is what I am trying to suggest in the testimony.

I think that is possible. I have worked with a number of these start-up companies that are looking to do really exciting things. They would love to have NASA as a partner, and you have got to figure out a way to find ways for NASA to be able to do that partnership on a very, very routine basis.

Ms. JOHNSON. Thank you. I know my time has expired, but yours have not, so I will relent and let them answer.

General SEGA. If I could follow that comment, our study task stated that any recommendations made by the committee will be predicated on the assumption that NASA's outyear budget profile will be constrained due to continuing deficit reduction, so we looked at a budget-constrained environment. We do believe, and we concur with what you were saying in terms of the long-term view, and strategic goals and objectives are a starting point and that there is a consensus about those strategic goals and objectives. For example, as we had many witnesses and did our work, we found little evidence that an asteroid mission, for example, is widely accepted, whether inside of NASA, outside in industry or internationally, and so it is important that there is clarity in terms of the direction and NASA's strategic plan can in fact with clarity identify what the trades are in that portfolio going forward and there is a starting point upon which some choices can be made.

Ms. BLAKEY. I think you will find industry also joining with others on the panel saying that absolutely partnerships, the ability to bring together public and private sector and international or conjoining resources is certainly an excellent step in the right direction, that if this Committee through the upcoming reauthorization process, because I would remind us all that it is not so far away again, that you all are going to have to tackle that would be excellent.

I also would say that regardless of destination, because there are conflicting views about destinations—you even hear them on this panel—let us keep in mind that building the capabilities to get into deep space, the ability, both in terms of heavy launch as well as crew capsules and tackling some of the research that is daunting right now still. We don't have all the answers on deep space radiation, for example, and issues of bone density. So there is some critical research that has got to be continued, but remember, when they supported the F–1 rocket back in the 1950s, they didn't know where they were going to go but it made all the difference, so bear that in mind.

Dr. PACE. Well, actually I was motioning to my colleague because I thought that he put his finger on it in terms of the people, that is, the combination of small satellites, suborbital missions, zero-G aircraft, things that provide really tangible hands-on experience is the most crucial thing to give people a sense of the future. Sometimes when it is said to me, "we have been to the moon already," I usually have to respectfully say, well, my father's generation went to the moon; we have not gone to the moon. That generation is past. We need to build and rebuild the people with the expertise.

One of the most exciting things about the commercial industries and the partnerships that Congressman Walker noted is that opportunity to provide for hands-on, real hardware and real flight experience, for which there is no substitute. And so I think the building of capabilities, whatever destinations we want to go, obviously I am a partisan of a particular approach, none of that is possible without hands-on expertise, and I thought my colleague really nailed that one.

Chairman HALL. The gentlelady yields back her time. I think that was a very good question that you asked, and I am sorry that that question wasn't put to the President of the United States before he ran a line through Constellation or he hadn't have talked to Bob Walker, General Sega, some of you who know much about what is going on, Norm Augustine, for one, who always said what we needed the funds for it, and the funds we needed and were requested were turned down. So we go from that.

At this time I recognize Mr. Sensenbrenner for five minutes.

Mr. SENSENBRENNER. Thank you, Mr. Chairman.

NASA was created in the 1950s in reaction to the Soviet Union launching Sputnik I, which ignited a Space Race beginning with the Mercury program. NASA's focus on putting humans into space served as its most high-profile and arguably the most exciting facet of the agency. Mission-oriented manned space programs have been the prism through which we judge the agency, and mission orientation back 40 years ago excited a group of students to go into STEM education, which we now call it today, and got us a generation of scientists and engineers.

The space shuttle, however, flew its last mission in 2011 and there is now a gap in domestic spaceflight capabilities. Instead, we rely on the Russian space agency to ferry American astronauts to the space station. The Bush Administration began the Constellation program to serve as the shuttle's successor but President Obama canceled the program. Fortunately, Congress has continued to see the importance of a heavy-lift rocket system and mandated

the Space Launch System and the Orion program in the 2010 NASA authorization bill.

Dr. Pace, I appreciate your comment. The stimulus act appropriated more funds in one act than this country has spent on NASA since its creation in 1958, and budgets and spending are an example of priorities, and in terms of having to seize the continued United States' preeminence not just in manned space programs but in terms of science and inventions and everything else that goes along with it ended up being washed away in the flood of stimulus funds.

Now, as this hearing has highlighted already, the President's approach to human spaceflight lacks a clear mission, and he is relying on the success of commercial space, which I agree is vital, but has dragged his feet on pushing human spaceflight at NASA. I strongly support a public-private partnership for our country's space policy. However, it is up to NASA to develop the heavy-lift rocket because the private sector doesn't have enough funds to do it by itself, and that heavy-lift rocket needs enough thrust to overcome the Administration's shortsightedness.

Now, by canceling the Constellation program, NASA has lost its international partners who supported a mission to the Moon. President Obama has taken a "been there, done that" approach, but we haven't been there for 40 years, and the international partners that would have helped us have never been there. If we cannot lead the world in space, China and Russia will inevitably feel the void that we left behind, and that will have a trickle-down effect on the number of people that we train as scientists and engineers to keep America's preeminence not in space but in practically everything else.

So Dr. Pace, would you please discuss the problems caused by the cancellation of the Constellation program, and what is needed from Congress in this current fiscal environment to ensure the success of the Space Launch System and Orion?

Dr. PACE. Thank you, sir. That is a tall order. I think one of the crucial things that the Constellation program was supposed to do was to provide a smooth transition for the workforce and for the capabilities the Nation had off of the shuttle program to whatever came next.

Mr. SENSENBRENNER. And we have lost that now.

Dr. PACE. And we have lost that, and the deep integration between low-Earth orbit and farther destinations that was hoped for I think is also gone. So I would first say that 2012 is not 2008. We are in a different and new situation today, and we have to look at going forward.

The primary—one of the primary problems, though, with the end of Constellation was again cutting ourselves off from our international partners who didn't see how they were going to participate, increasing risk to the International Space Station because while we certainly hope for and encourage and want to see the private sector take over that work, if there are delays, if there are problems, we don't really have a fallback option, so we are down to really a few critical paths for supporting the station. So the complementary nature between commercial programs and the Constellation program I thought was one of its strengths.

The lack of a clear rationale for human exploration beyond the International Space Station is another serious problem. The Administration's approach of being capability driven, while it has a certain logic to it, also has a lot of vulnerabilities, and historically, I think that a more strictly geopolitical approach such as I have talked about a post-Cold War approach for leading international cooperation would in fact be a better approach for the United States. There are some others that one could take but simply talking about capabilities absent a strategic rationale that is integrated with other U.S. national interests I think is a very, very fraught path as we are seeing today.

Mr. SENSENBRENNER. Thank you. My time is expired.

Chairman HALL. The Chair now recognizes the gentleman from Michigan, Mr. Clarke.

Mr. CLARKE. Thank you, Mr. Chair.

Funding for NASA is very important for many reasons but especially investment in NASA creates jobs. If we want to increase funding to NASA, we have got to speed up our Nation's economic recovery, and I have a couple of bills that I believe provide a very cost-effective way to strengthen our economic competitiveness, and that would be to invest in the city that symbolizes both U.S. manufacturing and has the assets to help make our country's economic capability stronger, and that is the city of Detroit. The city of Detroit is currently in fiscal constraints. It is facing its own fiscal cliff. I will be soon introducing a bill that will allow the city to refinance its considerable debt at a lower interest rate, saving money and likely stabilizing that city's financial situation. Furthermore, I am proposing to eliminate the capital gains tax on income on investment made in that city as a way to spur investment.

Saying that, in the city of Detroit, we have an extraordinarily high number of people who have lost hope because they are not working, yet throughout the metropolitan Detroit region, we have many employers who have thousands of jobs that are going unfilled because they can't find people skilled and qualified to be hired into those jobs. We have a skills gap in metropolitan Detroit as well as in this country.

Dr. Zurbuchen, from the University of Michigan, I know that you understand these economic challenges that we are facing in southeastern Michigan. How do you believe that investing in NASA innovation could help us close that skills gap?

Dr. ZURBUCHEN. Thanks so much for this question, Congressman.

I am the first university graduate in my family. The only reason I studied science, which is what I did, and the only reason I came to this country is because of the investment this Committee or committees ahead of it have made decades ago and because of the inspiration that came from the Space Program. I believe that that power of inspiration and investments that comes from this has a tremendous effect on the youth, the young high school student who is making decisions for her career and the future she has in front of her seeing that it is possible to make these dreams a reality.

So I do believe the inspiration aspect of NASA is a really important part and remains a very powerful force that this Committee should consider. Once we get them through the high schools and

into our universities, I believe the kind of diverse portfolio that I mentioned, the hands-on experience explains to our students that technology and progress is not so much just about talking about ideas; it is about making these ideas happen.

And you should be interested in knowing that, for example, at the University of Michigan with—this last year, something like 5,000 engaged students in activities, aerospace is the third-most represented theme following only biomedical and computer science, the ones you would have guessed perhaps initially. Aerospace is hugely represented because of the reasons that Congressman Walker and others have mentioned the tremendous power of the ability of actually putting these companies out there, trying to have new approaches of landing that rover on Mars. Some of my students were engaged in that. So I believe the hands-on experience that comes from the programs from NASA are a second aspect on a very important solution that you were mentioning.

The shops are coming. We have startups in aerospace. Some of these really surprising kind of changes from technology that was developed under NASA, for example, technology that they are now investigating under city sewer systems using robotics technology that was developed in NASA. General Motors, a company that you are very much aware of having tremendous autonomy, lessons learned in collaboration with NASA through these public-private partnerships that led to the robot on the space station. So I believe that there is multipronged aspects that relates directly to the bottom—not just to the bottom line, to the top line to what our economy does and how—what the shops are that are being created both in Michigan but they are all over the country.

Mr. CLARKE. Thank you, Doctor.

Mr. Chair, do I have time for another question?

Chairman HALL. I beg your pardon?

Mr. CLARKE. I yield back my time.

Chairman HALL. The gentleman yields back his time.

The Chair now recognizes Chairman Smith for five minutes.

Mr. SMITH. Thank you, Mr. Chairman.

General Sega, let me address my first question to you. Your report showed that there is not much support in the scientific and space community for a mission to a near-Earth asteroid in 2025. Is such a mission absolutely necessary to help us get to Mars or are there alternatives? And are there alternative missions as well to replace that mission to the asteroid?

General SEGA. As we look at the human mission to an asteroid that is in 2010 National Space Policy of the United States, in addition to not being widely accepted, there were some shortcomings noted by some of the people that appeared before the Committee. A note is that as we look back in time, there have been several Presidents that have talked about Mars. The rhetoric toward that as a destination was noted by the Committee. We also recognize that there are different paths that one could go if that was in fact the chosen destination for a human mission and that it would maybe look at integrating some of the other aspects of NASA's work. For example, if that was the strategic goal, then you would look at the robotic missions that would support going there.

Mr. SMITH. General Sega, do you think we should reconsider that mission to the near-Earth asteroid?

General SEGA. The Committee didn't address that directly but there were many questions that concerned that as the path forward.

Mr. SMITH. Okay.

General SEGA. Other work in terms of technology, aeronautics, getting to the atmosphere of Mars, out of our atmosphere in science could be focused on the strategic goals and objectives.

Mr. SMITH. Okay. Thank you for that.

Dr. Pace, what do you think the American people would like for us to do in space? Obviously, the Hubble is a popular curiosity that generated a great amount of interest. More specifically, how do you determine that coincidence between popular support and missions that are scientifically justified and missions that can be just abide by budget constraints as well?

Dr. PACE. Sure. One of the patterns you see in public opinion is U.S. public opinion has been actually remarkably stable for space activity. It was never as large as people thought it was during Apollo and it has never been low as people thought about afterwards.

So the American public have sense, I think, that we are an exploring nation, we are a pioneering nation, and they expect or assume that our leadership is in fact doing that and working on it and they trust that that is happening. So when things like the shuttle program ended without really a clear path after that, there was somewhat a sense of shock or concern, not because they agreed or preferred one path or another but because they sensed, well, wait a minute. Isn't someone working on this? Isn't there a path forward.

The—getting to specific missions, I think what you see over and over again is people have an interest in life. They have an interest in people, the sense of direct—so when there is the possibility of organic life on Mars, you see lots of interest. Much to the disappointment sometimes of the geologists who think they are doing important work, too.

Mr. SMITH. Right.

Dr. PACE. But life science and that sense of personal connection, space tourism which is talked about, that sense of personal participation and connection is what I think the American people are——

Mr. SMITH. Would you put in that category Earthlike planets as well?

Dr. PACE. Absolutely. Absolutely. The growth of a number of Earthlike planets——

Mr. SMITH. Okay.

Dr. PACE. —to the Kepler mission has been very, very exciting. I think that with the James Webb Space Telescope to see deeper into the galaxy and things we have never seen before will inspire that sense of wonder that the American people assume that their country is going to be a leader in doing.

Mr. SMITH. Okay. I agree with that. Thank you, Dr. Pace.

And Congressman Walker, final question for you. How do we determine the balance between robotic and human missions? There

are advantages and disadvantages to both, but is there any way to try to achieve a balance?

Mr. WALKER. Well, I think clearly there needs to be an understanding of what humans can do best and what robots can do best. The robots give us tremendous amounts of information, but in general, they find what we sent them there to find. It is based upon our belief of what they might be capable of finding. Humans have the advantage of going and finding things that we never expected to find and never expected to see. Someone said the other day that the two small rovers that were on Mars for many months did, in the whole time that they were there or the whole time that they have been there, about the same amount of work one human could do in a day-and-a-half because is it in fact—it is the human ability to process information in remarkable ways that is needed.

And so I think you do strike a balance. The precursor missions are always going to be robotic probably. There are tremendous science missions that you can do with robots. But in the end, you want to put humans into a place where humans can find only those things that humans are capable of finding.

Mr. SMITH. Thank you, Mr. Walker.

Thank you, Mr. Chairman.

Chairman HALL. I am aware of Mr. Walker's problem space and time-wise. We excuse you at this time.

Mr. WALKER. I am fine, Mr. Chair.

Chairman HALL. You are okay?

Mr. WALKER. I have had my office tell my appointment that I will reschedule with them and so on, and so I am fine for the moment.

Chairman HALL. Okay. Thank you.

The Chair now recognizes the gentleman from Michigan, Mr. Curson, for five minutes.

Mr. CURSON. Thank you, Mr. Chairman. And thanks to all of you that testified with this excellent testimony.

I am from an industry that has benefitted much from NASA and the technologies and everything that they have spawned from their research and the brilliance that has come out of there—I come from the auto industry and everything from metals to paint to weight, and I truly hope that NASA gets a long-term presence that they are looking for because it benefits this entire country. But also the stimulus that we have talked about that has been kicked around here a little bit saved that same industry that I came out of, and had it not been for that stimulus, we have might have been in a depression and not be able to talk about any funding.

So with that out, I would like to direct a question to General Sega. You testified that NASA needs personnel flexibility, including the ability to conduct reductions in force and hire contractors rather than civil servants in select instances. I would like to know if this is because there isn't a long-term commitment to the program and you need to be flexible bringing people in or out, or do you believe even if there is a long-term commitment if that would be your strategy on personnel? And what provisions can NASA make for the retraining of those highly educated NASA scientists and technicians if you end up with a glut of those people, which there is going to be right now from what I understand? And is the commercial

market large enough to absorb these scientists and these highly skilled people that were trained with tax dollars and they are going to carry knowledge that nobody else possesses that could be valuable to our country? Can the market absorb those?

General SEGA. Congressman, one of our tasks was to examine NASA's organizational structure and identify changes that can improve the efficiency and effectiveness of the mission activity, so that is how we address that.

As you arrive at new strategic objectives and goals and then NASA creates a strategic plan to accomplish those, we recommend the flexibility, not necessarily, how it would turn out in terms of the ability to look at personnel in infrastructure aligned with the strategic goals and objectives in an implementation plan.

So we did note that the jet propulsion lab is an FFRDC-type structure and it is contract folks there that are engaged in many aspects of research development and operations for their satellites. So in different centers have a different mix in terms of contractors and civil servants. There were about four of them that were about 50/50. There is about three of them that were quite high in terms of contractors to NASA civil servants, one that was higher in terms of civil servants than contractors, but there is more of that flexibility of doing what that center would be expected to accomplish in a more integrated way. And so it was the flexibility rather than a specific solution that we are recommending.

Mr. CURSON. Hnot to be aow do we ensure that NASA's research talent pool and facilities are not acquired by foreign interests that may be harmful to our national interests? I guess the General, I direct that toward you again.

General SEGA. That was not addressed in our study in terms of the United States versus foreign ownership of companies.

Mr. CURSON. And I believe you testified in your written statement that NASA's infrastructure flexibility—the ability to dispose of property it no longer needs. Would this be included and what could be purchased by foreign countries?

General SEGA. I don't really recall that we have specified or even considered in our deliberations the nature of the entity that would be a potential buyer of the facility. I do want to give you an example of a visit that I made to Plum Brook—it is in Ohio—where they have a large chamber and they test fairings separations. And they—a great facility. Some of NASA's missions need that, but it is a facility that also has the capacity for other work. And so it was ESA that looked at doing some work in that facility. They were also discussing with JAXA and SpaceX to do work in that facility. And so it would be—some aspects may be appropriate for a sale, but others may be just greater utilization of the facility in more creative ways.

Mr. CURSON. Thank you.

If I may, one question to Congressman Walker. You talked about the possibility of for-profit companies joining in with NASA on particular research. We all know there are great minds out there right now thinking about farming in space and mining in space, which would be great projects to work together. Are there really companies out there that could afford the funding to do that research to

join in with NASA to help NASA become a viable program for the long-term?

Mr. WALKER. Absolutely. I mean you have companies right now that are creating spacecraft that you do have working relationships with NASA but we would love to have closer relationships and look toward the future. We announced a company just last week that is looking to go to the moon. Certainly, NASA's expertise in that area would be invaluable. And these are companies who are perfectly prepared to pay NASA for utilization of their facilities and utilization of their talent. And so there are lots of opportunities out there that could be expanded even more into the future.

You mentioned the automobile industry. The automobile industry is in the process of developing autonomous vehicles. Nobody has done more elaborate work on autonomous vehicles than NASA has done. My guess is that there have been some partnerships in that, but those are partnerships that could be expanded.

Mr. CURSON. Yeah. Thank you, Congressman.

And I yield any time I might have left.

Chairman HALL. The gentleman yields back.

The Chair recognizes the gentleman from Mississippi, Mr. Palazzo, for five minutes.

Mr. PALAZZO. Thank you, Chairman Hall.

The hearing today is especially appropriate considering the upcoming NASA reauthorization of some of the recent bills we have passed, including the indemnification bill that so many on this Committee wanted to see and supported.

As has already been expressed here by other Members and our witnesses, I am concerned with the vision for NASA going forward and the budget issues that are causing such grief in our short- and long-term programs and missions. What are our long-term goals for NASA? How will we form a strategy that takes into account all NASA initiatives from space and earth sciences, human space exploration, and aeronautics to STEM education? The NRC report attempted to answer these questions and discuss some of the paths NASA could take. None of them will be easy and our job will only become more difficult as budgets shrink.

NASA, the Administration, and Congress must do a better job of informing the American people about the important work NASA does and the overwhelming benefits our society reaps as a result. Maintaining our space leadership in the world is extremely important and is worth investing in, but we must not forget that an investment in NASA is also an investment in research and development for future technologies. NASA has a proven record and thousands of examples in everyday technologies we simply could not live without in 2012.

I would like to remind everyone the speech that President Kennedy gave at Rice University in 1962. He addressed the U.S. effort to put a man on the moon and used that famous line—and I am paraphrasing—but Kennedy said we did these things not because they are easy but because they are hard. The questions we must answer and the choices that must be made are anything but easy. But like Kennedy, we should not shrink back from them simply because they are hard.

NASA must step up to this challenge or it risks its legacy of success and leadership in space. That is not an outcome that anyone in this room wants to see happen. So I thank you all for sharing your comments with us today, and I believe I may have time for one question.

So Ms. Blakey, given the end of the shuttle program and a lack of a clear strategic direction, how does the uncertainty threaten our industrial base and can you characterize the capabilities that are at risk and perhaps even give us some examples?

Ms. BLAKEY. Well, certainly, the cancellation of Constellation was extremely disruptive from the industrial base standpoint. At one point, we had more than 12,000 contractors working down there. At this point, it is right at 1,000 and diminishing. All those people, their skills, expertise go elsewhere and frankly may very well go into other industries. So we are extremely concerned that there be the kind of stability, the kind of long-term programs, and ones that really do tap the outer edge of design talent, the kind of R&D that is really fundamental for us to maintain our global leadership, because that is what is at stake behind the many, many companies, universities, et cetera, that are all combining to support our space program.

Mr. PALAZZO. How do you replace that lost talent? Is there a cost in—financial cost and is there a cost in time as well? I mean will there not be a gap before we could possibly replace that talent?

Ms. BLAKEY. There could very well be and we are quite worried about that because as much as we support STEM programs at all levels of education, you still have to have the opportunities for young people to see in front of them that appear to be important and exciting. And if those opportunities aren't clear when they are making choices, whether it is high school, graduate school, et cetera, they will definitely go elsewhere and we do not see the kind of upsurge that we should be seeing in engineering and other science talent right now. It is a problem. And we have a huge amount of retirees in the industry. We have an aging population. So we are going to see a real bathtub if you will where we don't have the kind of people we need, especially as we have to step it up.

Mr. PALAZZO. Thank you for your answer to my question.

I would like to just—in all fairness, I do have a couple more questions but I am going to yield back my time. But I would like to say I do agree with our colleague from Detroit. I believe he stepped out. I am all in favor of eliminating the capital gains tax but not just for Detroit but for every American. So thank you. I yield back.

Chairman HALL. Okay. The Chair now recognizes Ms. Bonamici of Oregon for five minutes.

Ms. BONAMICI. Thank you very much, Mr. Chairman. And thank you to all the witnesses for your testimony.

I wanted to follow up on some of the discussion we have already been having about education, especially STEM education. And Mr. Clarke brought up the skills gap. But I also want to talk a little bit about the importance of educating the public about the benefits of the Space Program, and there are some testimony that has been provided that begins to touch on this.

Ms. Blakey, you talk in your testimony about how Space Programs have improved our lives from vaccination research to guiding first responders to weather satellites and missile detection satellites. And then Dr. Zurbuchen—I hope I got your name right or close—you talk about how do we define the purpose and meaning behind exploration in space within a society that does not always see a tangible benefit. And Dr. Pace, you say that in today's environment with massive debt and an anemic economic recovery sustaining discretionary expenditures for civil space exploration will be especially challenging unless there is a clear rationale linking such efforts to broader national interests that can be supported in a bipartisan manner over many years.

Now, I know there has been some discussion already about the skills gap and of course STEM education. I want to point out that the role of NASA in promoting STEM education should be more clearly articulated in NASA's strategic plan. But what I would like you to talk about is what, if anything, is the industry doing to convey to the public the benefits of space exploration? In other words, how can the contributions of our Space Program to national interest be communicated not just to stakeholders but also to the public at large?

And Ms. Blakey, if you would like to start, please?

Ms. BLAKEY. Well, I thank you very much for the opportunity to expand on that a bit because we did put a great deal of effort into this brand new report called "Space in Our World" which, believe me, we will make certain that every Member of this Congress and the new Congress has a copy because you are all ambassadors on this front. But we have also looked at the fact that through social media this could be accessible to every American. We have been Tweeting it, we have been putting out specific nuggets if you will of examples. We are looking to excite young people at the universities because there are examples in here of where work in a variety of universities and the private sector have kicked off enormous benefits for our society.

So I simply would say that it is something that I think we need to do a good job on because I do not believe the public has any idea how, in their daily life, everyday life, they are over and over again using the work that comes out of our NASA programs and our Space Programs broadly, including NRO and some of our classified programs. It all moves out eventually into the economy and it has been a huge spur for the economy.

Ms. BONAMICI. Thank you. I look forward to seeing the report.

Anyone else care to add to that? Dr. Pace?

Dr. PACE. I would say from experience of being at the university—I teach both graduate and undergraduate students—and many of them come and take courses in space and space policy who are not space enthusiasts. They are international affairs students, political science majors, economics people. And to me it is always very gratifying as they hear about the relationship of space to the economy and the relationship to our international relations just how critical they realize this subject is.

Many of them will come and say after going through the course they walk outside and they have a new perspective on the sky above them. They had no idea that all these things were going on

overhead—remote sensing, GPS systems, communications satellites—how deeply embedded space in the entire critical infrastructure of the planet. And it is almost invisible. But then once they realize that is there, they take on a new appreciation for it. They take on an appreciation for the immense symbolism that space has and how it represents our strategic relationship with our allies which is Japan and Europe, how the Clinton Administration used brining the Russians into the Space Station program—very controversial—but as a way of symbolizing a post-Soviet relationship with them.

So the really macro sweep of international affairs, the centrality to the economy is something that students then come to know and appreciate. And I don't know how to do that for the public as a whole but I know we can certainly do it for students and it happens over and over and over again as soon as they see that and as soon as it is laid out for them.

Ms. BONAMICI. Well, thank you.

And Major General, go ahead. I have a few seconds left. Go ahead.

General SEGA. Okay. I just wanted to note that our committee did look at that as well and NASA in our view is making some very positive steps in communication with regard to social media for example and their STEM programs. I personally was one of those that was inspired as a young boy living in northeastern Ohio during the Mercury, Gemini, and Apollo programs to studying math and science and ended up taking my first airplane ride of my life from Cleveland, Ohio, to Denver, Colorado, to go the Air Force Academy. I had never been in an airplane prior to that time.

But in our study, we also looked at the events that are clear and compelling such as landing the Curiosity that the communications to the public was outstanding. And so in route to identifying clear strategic objectives and goals and then developing a strategic plan for NASA, some of that story becomes clearer and easier to tell.

Ms. BONAMICI. Thank you. Thank you.

I am out of time. Thank you, Mr. Chair.

Chairman HALL. The gentlelady yields back her time.

Congressman Brooks from Alabama, five minutes.

Mr. BROOKS. Thank you, Mr. Chairman.

Dr. Zurbuchen and also Ms. Blakey, your testimony—in particular, Dr. Zurbuchen—highlights the importance of maintaining the pipeline of engineers and scientists to ensure that we continue to innovate in the future. With respect to both of you, what are your recommendations for a program that provides opportunities to our graduate and post-doctoral students to the benefit of future U.S. leadership in space?

Dr. ZURBUCHEN. Thanks so much, Congressman. My personal feeling is that such a program would be hugely advantageous for this Nation and could in many ways in fact enable ideas that were talked about on this panel. I think in general we have tremendous interest in our talent—in some of our talent to really engage in this, and such a program that you mentioned I think will be very positively reacted upon.

Ms. BLAKEY. I must also tell you because I have had the opportunity to go to almost all of NASA's centers around the country as

a member of the NASA Advisory Council, I have been very, very impressed with the degree to which local university talent is integrated into many of the NASA programs. JPL, there is practically no one under 30 it appears as you go around the entire facility. So I mean there is a big emphasis on trying to pull in young people both at the undergraduate and graduate level.

I will also recommend this: if you all haven't seen two videos that are out there both stemming from the Curiosity rover, I would recommend them. One of course is "7 Minutes of Terror," but it has relatively young engineers talking about that 7 minutes when they did not know whether in fact the Curiosity rover was on Mars. And the other one is a very funny rap video, again done by young people in the NASA framework, all about how exciting it is to work at NASA and how exciting it is to be involved in the space program. Those things are getting millions of hits on YouTube. So there is a lot going on that some of us—at least I don't often see.

Mr. BROOKS. Do you have any specific suggestions of what the Federal Government should be doing to encourage STEM education at the collegiate level or postgraduate level?

Dr. ZURBUCHEN. My personal recommendation would be to focus on these modest and small-scale programs with tremendous emphasis and really make sure that, for example, suborbital programs and programs that support small-scale missions, as well as explorer programs and so forth are funded at the level that really makes the substantial impact that it can have towards talent development. In my opinion, there is no other investment at the collegiate level that will have more impact relative to just a hands-on experience in the development of talent for industry and for NASA than investments like that.

Ms. BLAKEY. I also would say that you see a great deal of emphasis now in industry on pairing with universities on specifically focused programs that often involve research for undergraduates that can take them all the way into the graduate level with internships in the summertime in those companies and going back into the university where the curriculum is also tailored to becoming a professional with a high degree of expertise in one or another of these subspecialties. So there is a lot more that is no longer generalized but is really going into the engineering schools and saying let us help you teach so that people come out with very concrete interests and ambitions at the end that are highly marketable.

Mr. BROOKS. All right. Congressman Walker, General Sega, and Dr. Pace, briefly, legislation has been introduced calling for lengthening the term of the NASA Administrator as a way to help stabilize NASA's strategic direction. Testimony that we have heard makes it clear that the largest problem is not at the NASA level; it is a problem with national leadership and coming to a consensus between the White House and the Congress. In your judgment, would a longer term for the NASA Administrator have a positive effect on NASA?

Mr. WALKER. I think separating the NASA Administrator from the political structure of the country would be a mistake. I think that that kind of a situation would keep NASA out of the mainstream of where political thought is going and I don't think that that would be the wise course for the Nation at this point.

Mr. BROOKS. Thank you.

General Sega?

General SEGA. Sir, our committee did not address the term of the NASA Administrator.

Mr. BROOKS. Do you have a judgment—an opinion?

General SEGA. I don't.

Mr. BROOKS. All right.

General SEGA. I haven't thought through it.

Mr. BROOKS. That is fine. Thank you.

Dr. Pace?

Dr. PACE. As an academic, I would answer it depends. I would say that I think a slightly longer term or a set term could be useful, but I share Congressman Walker's concern about making sure that there is acceptance of that on both—the part of both the House and the Senate—if that was the judgment of both House and Senate that a longer term would be part of that stable approach, then I think yes. If there wasn't such agreement, then I don't think it would be terribly useful for the reasons he described.

Mr. BROOKS. Thank you, Mr. Chairman, for the time allotted. And also thank you for the opportunity to serve under your leadership over the past two years as Chairman of this Committee. It has been a real pleasure.

Chairman HALL. I thank you. And that might be one thing the House and Senate could agree on. They would both be against it I think.

I recognize Mr. Miller, the gentleman from North Carolina.

Mr. MILLER. Thank you, Mr. Chairman.

Dr. Pace, the answer "it depends" would also qualify you to be a lawyer.

Congressman Walker, I was interested in your idea of corporate sponsorships. I am kind of old-fashioned. I liked it when taxpayers built stadiums that were named after our honored war dead instead of selling naming rights. And I just can't quite imagine that picture of Neil Armstrong and Buzz Aldrin on the moon or Ed White walking in space in spacesuits that made them look like NASCAR drivers. So a part of me rebels at it in the first place, but second, I worry about the stability of the funding. We have heard a lot today about the need for stable funding and stable leadership at NASA. Sponsorships, naming rights tend not to be a particularly stable source of funding because corporations merge, they get acquired, they run into trouble, they have to scale back. Will that be a stable source of funding?

Mr. WALKER. Well, certainly, there is instability in that but, look, the appropriations process has also been a very instable—or unstable source of funding for NASA as well. And so, this is one way of reaching out to bring additional resources into NASA. And it goes further than that. These are industries that take a huge interest in NASA's activities. People who provide sponsorships then build out. We have been talking here at this table about the need for NASA to be recognized broadly in the community. It is a way of assuring that.

You mentioned NASCAR. The companies that provide those sponsorships take a huge interest in what happens in NASCAR and particularly with the teams that they sponsor. And they are

a part of expanding the acceptance of the NASCAR racing well beyond the day's activities on a Sunday at the racetrack.

And so this is an opportunity for us to have an outreach that goes to people who actually then have some skin in the game and I think it could be an extremely important way of bringing resources into an agency that is badly in need of significant resources for the future.

Mr. MILLER. I want to make it clear I wasn't picking a fight with NASCAR. I am from North Carolina.

Mr. WALKER. I didn't think you would.

Mr. MILLER. I didn't run for reelection but I do want to be able to go out in public.

There has been a lot of discussion of public-private partnerships. Obviously, we do need to think about commercial applications of our space technology and our capabilities, but I worry. We have had proposals, discussions in this committee of privatizing the national weather service, which is entirely built with taxpayer-funded research. It is a capability that has been entirely provided as a public service built by taxpayer funding. And the proposals seem to be coming from a company that wanted to buy the National Weather Service, have monopoly power, and sell the data for a profit. Since there is not an active market in National Weather Services, pricing it seemed to be kind of hard and the public—the problem of having that information provided for profit by somebody with a monopoly power—worried me.

It struck me as what happened with the sale of state-owned enterprises in companies—industries in—as the Soviet Union dissolved to oligarchs. I want to make sure we are not taken. How do we make sure that we are not taken in these public-private partnerships and that we aren't giving a monopoly power for something that perhaps should be provided as a government service?

Mr. WALKER. Well, I would remind you that one of the problems we have with the Weather Service right now is the fact that they haven't been able to fly their new modern satellites and so on, and we risk a gap in a lot of valuable information going forward because the government hasn't been capable of moving forward. And so, there are problems on both sides.

I would say to you that that is where the whole issue of oversight of all these activities where this Committee would play an extremely important role in assuring that the kinds of private-public partnerships that were entered into would in fact be in the public interest. And there are a number of ways that you can write bills to assure that kind of activity. As I mentioned before, you can do it through an FFRDC kind of mechanism where the Federal Government remains actively involved in what those companies are doing, how those companies are doing their job, and in fact provides an annual stream of funding so that there are ways of structuring this that would assure that the public interest was still maintained.

Mr. MILLER. Mr. Chairman, my time is expired.

Chairman HALL. I thank the gentleman.

The Chair recognizes the gentleman from California, Mr. Rohrabacher.

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

Let me also echo the gratitude that I have for having served with you and you have provided excellent leadership to this Committee and it has been—over the years, just an honor working with you and with those who will be leaving us as well.

From our last question, let us just note that we have a trillion dollars that we are spending more than we are taking in. One-third of the federal budget now is debt. I mean we are increasing in debt. Thus, if we are going to do things in the future and if NASA or any of the things that we are going to do in the future are to survive and/or to actually play an important role in our country's future, we have got to be creative. We have got to be creative and we have got to find new approaches, and that I think is the number one commitment that we have got, because otherwise, it is just going to fall apart.

And I have a lot to say. That when you have a trillion dollars more in debt that you have to deal with, I don't believe the American people are going to put NASA on the top of their priority list, which means we have to be even more creative for those of us who do believe the importance of space-related assets.

Let us just note that for the hearing today we have already talked about how this infrastructure, this invisible infrastructure that we depend upon—I mean I remember when telephone calls cost so much money. It has been space-based assets that have brought that down. GPS—people have no idea the potential—even future potential of GPS. We are just now experiencing that. And of course our national security, weather, all that has been talked about. These are all things that deal with space-based assets and I believe that NASA should be the one who actually is pushing the envelope and what space-based assets will benefit humankind in the future.

Let me just note that one thing that is sure, if you are going to have space-based assets, we have got to have an environment in space that is capable to use. And today, that is under threat. And if there is anything that NASA—that I would see that NASA can take a responsibility for along with a partnership, a global partnership and lead the way, it is making sure that we clear the debris from space so that we can have space-based assets. If we don't clear the debris, the debris will clear us out of space eventually. And we haven't really focused on that. And I think that is something—maybe that is one of those challenges that young people and everybody else can understand.

The other challenge perhaps, I don't know if anybody noticed—let me see if I have the actual number—yes. Did anyone notice 2012XE54? Anybody notice that? Well, that happened to have been an asteroid that was discovered Sunday, and yesterday, flew between the Earth and the moon. That asteroid had the same destructive power as the Tunguska asteroid that destroyed hundreds of miles of Siberia about 100 years ago, yet we didn't discover it until Sunday. Now, those are huge challenges that we need to take up. We are not going to have space-based assets unless we clear the debris, and we are not going to have a safe planet unless we can detect and deflect these type of challenges.

I would hope that NASA, Mr. Chairman—if I have any say in it, NASA should be taking up that challenge so that we can use space

for the betterment of mankind in the future. And you have got 45 seconds to comment on my pontification. Bob, do you want to——

Mr. WALKER. Well, certainly, the issue of space debris is a crucial issue. The commercial industry is facing all kinds of problems these days with monitoring that, and much of what we monitor is larger than some of the particles that could actually cause real damage in space. And so that is a real problem that needs to be addressed. And there are actually some people out there in the private sector that have some interesting ideas about how we could do that.

General SEGA. As our committee looked at the issue of asteroids, I commented on the human mission to them, but I also recognize the importance of increasing our understanding of the asteroids, and currently, there is a satellite that is in that area.

Mr. ROHRABACHER. Well, thank you very much.

Chairman HALL. The gentleman yields back. I don't believe we—well, yeah, we have one more here.

The Chair recognizes Mrs. Edwards from Maryland.

Ms. EDWARDS. Thank you, Mr. Chairman.

And I just want to echo how delightful it has been to have you as our Chairman for the past couple years. I really both enjoyed your company and your service on the Committee and so I thank you for that and for tolerating me occasionally.

I was just—I am a Twitter follower of NASA's and I noted that NASA has about 3.2 million followers, which is not insignificant. It is not as much as the President or Oprah, but it is more than the First Lady and RG3 and NASCAR. And so there are people out there who really have an interest in NASA and value NASA and how we can capture that I think so that it also translates into support on a fiscal level I think is the challenge given the range of activity that we expect of the Agency. And just this—you know, over those last couple hours or so as I am following my Twitter feeds, then I noted that one, NASA assures us that the world is not going to end on December 21 in case anybody wondered, and that the hashtag Curiosity was the fifth-most followed or used hashtag over this last year, which says to me that, especially the Curiosity rover—it is striking some kind of chord in the public. And I think that is actually a good thing for us because I think it is important for the public to embrace NASA.

When I was growing up, our embrace of the Agency was because of the Apollo missions. It was sitting in, you know, kindergarten and 1st grade and whatever those other grades and watching the liftoffs. And that inspired a generation and inspired a nation. And I think Administrator Blakey, you pointed out that it requires that kind of public inspiration in order for us to generate the support for the other areas of the work that the Agency does.

I want to think outside the box in a way about what it is that we can do to strengthen the fiscal house of the Agency, and one of the things I would like to look at, especially where science is concerned, is that the difficult the Agency has in doing science on a year-by-year basis, it really doesn't make any sense. It is not what you generally find in university and other kind of research where you know as an investigator where you are starting, what your resources are over a period of time, and then you can plan out the investigation.

And some of what we saw, for example, with the James Webb Space Telescope is that with all of these different—and there were a lot of problems—but all of these different levels of funding from one year to the next year and not knowing and reprogramming and things that, in fact, you have instruments that sit around that aren't supposed to be sitting here because they are supposed to be up there, and then you actually end up over a course of time spending a lot more money. And so I wonder if I could hear from any of you about the idea with respect to scientific funding, agency funding, that if we went to, you know, a two year, a multiyear funding stream just for these programs understanding that it is different than funding other kinds of things that the government does. And I just wonder if you have some comments about that?

Dr. ZURBUCHEN. I have currently eight Ph.D. students who are supported by funding streams that you are talking about. I know firsthand the difficulty of managing these young people's lives in an environment in which decisions can happen at—on a week-to-week basis and all of a sudden their certain funding stream disappears. Once we lose a Ph.D. student like this, for example, we will do whatever we can as a university to cover that Ph.D. student through, but we have many cases, especially kind of in areas where space interacts with biology in the past where we lost something like 30—just in our university alone 30 Ph.D. students in a queue that never came back. And so tools that will create stability in that regard would that be tremendously I think considered a potential fashion from people like me and others.

Ms. EDWARDS. Congressman Walker, I wonder if you could comment. You have been in this place on an idea like that and where we might be able to take it.

Mr. WALKER. Well, I have long believed that we do great damage to our science programs with annual appropriations process. The fact is that you do have to have a long-term outlook when you are doing science whether it is space science or bench science. And so we have a real problem in that we have too often scrubbed the authorization process in favor of the appropriations process. I mean one of the great reforms around this place that would work would be to actually enforce the rules of the Congress that say that you have to have an authorization in place before you can pass an appropriation because the fact is we need to have the stability of long-term set policy in order to do science well. And by abandoning authorization process too often, we have put the policy decisions in the hands of the appropriators and they have a one-year horizon. One-year horizons do not work in science.

Ms. EDWARDS. Thank you, Mr. Chairman.

Ms. BLAKEY. If I might, I would mention one other thing because there is good precedent for this in terms of some defense programs. The industry would like to see more use of multi-year in terms of complex development programs, but when you look at those in the DOD arena, you do see that it has been an excellent force for holding down costs and having the kind of stability that is needed. So there is precedent.

Chairman HALL. The Chair at this time recognizes I believe Mr. Hultgren of Illinois for five minutes.

Mr. HULTGREN. Thank you so much. And Chairman, I just want to also thank you for your great service and your great work as Chairman. I think it has been really a good couple of years. I have sure enjoyed my time on the Science Committee and wish I could stay longer.

I also have enjoyed seeing you each time in Committee. It reminds me of my funeral director father, what he often says is that it is always better to be seen than to be viewed. And so I appreciate your—that is my dad's line—but great to be with you and appreciate all that you have done for us and for our Committee here.

I also want to echo and agree with my friend and colleague Congresswoman Edwards that we have got to start thinking more long-term when it comes to NASA and science. I think it really puts us at a disadvantage to so many other nations who are thinking 5, 10, 20 years in the future, and we are lucky if we are talking one year. More oftentimes, we are talking about 90 days. You know, like the continuing resolution that is just kicking something out a little bit further. We have got to change that and we have got to reach across the aisle to make sure that that happens.

So thank you all for being here. This is such an important discussion and something that I am passionate about. I do want to just ask a couple quick questions with the few minutes that I have. First, General Sega, I wonder if I could address to you your thoughts. Would the NRC report have had the same tenor and conclusions if President Obama had not cancelled the Constellation Program four years ago?

General SEGA. The factors that brought us to a point that we talked about in terms of transition was also the—terminating the shuttle program and then something else follows it, and the ability to have a consensus on strategic objectives and goals, this longer-term thinking is important and—to be able to have it for long-term. Clearly, it costs us Administrations; it costs us terms in Congress. And so I—the study was prompted by Congress, clearly, to NASA and then to the NRC, but the issue of the longer-term piece, I think that would be an enduring theme regardless of some other events.

Mr. HULTGREN. I wonder if I could ask the other folks here starting with Dr. Pace if you wouldn't mind your thoughts of how you think these results and conclusions would be different if the Constellation program hadn't been cancelled.

Dr. PACE. Well, I think there is really two parts to the disruptions that occurred. One is the Constellation program itself and the industrial base impact, and I think certainly we would have had maybe a slightly different tenor if that program had not been cancelled. But the deeper problem really is the policy. Okay? The National Space Policy in 2010 I think is actually quite a good document. I think it is very thoughtful, very balanced; there is a lot of good material in it. The part that, as a policy professional, sticks out for me is the section on civil space exploration, the asteroid and Mars aspect of it, which to my mind really comes out of a bit of left field. It didn't have an international context. It didn't have a commercial context. It wasn't mindful of the industrial base realities. And so it is really distinct from the rest of the policy.

I think if that mistake hadn't been made, I think you could have had a more rational discussion about how to either moderate,

change, turn, revamp the Constellation program into a way that would have been acceptable to the Administration going forward. So as in most things, it is really policy choices that are at the root of the issue. What is the strategy you are following? Then, the programmatic outcomes and the budgetary outcomes really follow from that. So that is where I would really point.

Mr. HULTGREN. Thank you. I ask the other three members if you would have any thoughts on that. I have just about a minute left but——

Ms. BLAKEY. Certainly, the variables at the industrial base, the companies involved that have had to deal with this, it has been very difficult. We feel very strongly moving forward that it is important to maintain both the emphasis on commercial crew, commercial resupply for ISS—we have got to keep that on track—and at the same time have the ability through SLS or Orion to get to deep space. Those two things are parallel tracks and they are both very important.

Mr. HULTGREN. Yes.

Mr. WALKER. I just would comment that I think it has to be recognized that financially, the Constellation program was an—in an unsustainable cost profile and it was about to eat alive the science programs and a number of other things inside of NASA at the kinds of costs that it was accumulating. And so, you have to look at it in terms of where would we be in terms of those costs undercutting other NASA programs if it had not gotten the kinds of money that Chairman Hall referred to earlier? Of course it could be done if you gave NASA an additional $3 billion. No one believed that NASA was going to get $3 billion at that point.

Mr. HULTGREN. Well, again, thank you all for being here. I think these are important discussions. My hope is that we can continue those and really have a great vision for NASA and from NASA into the future. So with that, I—again, Chairman, thank you for all that you have done for us. I appreciate your service so much and your friendship and look forward to working together for a long time to come. Thank you.

I yield back.

Chairman HALL. Thank you. You have my assurance that we will work together. And for your undertaker father, let me pass on one to him that my undertaker uses on me. He says don't worry about it; if you don't like flowers, they will finally grow on you.

Now, I think Mr. Clarke has asked for recognition.

Mr. CLARKE. Thank you, Mr. Chair. I really appreciate the opportunity. And I briefly wanted to ask everyone for their comment on how NASA, long-term strategically, can work more effectively with the private industry. That is an open-ended question but I will focus on two specific areas: one, with technology transfer on how the transfer of NASA's research to private industry, maybe to other federal agencies could play a larger role in our strategic vision for NASA. General Sega, you could also address that if you wish. And the other issue is how we can best restructure NASA in a way that would likely need Congressional authorization. These are issues that were raised by Chairman Walker with his illustration of let us say a sponsorship of one of our missions, although I prefer the

wolverine rover painted in maize and blue I think would be more appropriate than the Go Daddy rover.

But in any event, Congressional authorization needed to restructure—to promote the restructuring of NASA that could lead to more effective private partnerships and how do we strengthen the role of technology transfer in NASA's strategic mission?

Mr. WALKER. Well, quickly, I will give you one. There are a number of ways that you could do this, but the Aldridge Commission recommended that the centers be turned into FFRDCs like operations, that they would have to be modified, that not all centers do research and development. So that they would be structured in a way that would allow them to receive both public money and private money into their operations. And I think that something like that is certainly one of the places it has to look. Look, I mean one of the things that the NRC said was that the alternative to that may have to be the closing of some of the centers, or, the reduction of the size of NASA. This is the way that you can begin to look at how you keep the centers in place, how do you make them into viable economic units inside the communities that they have and for the Nation? And, I think that this Committee needs to look at how you might restructure them in a way that allows them to attract both private and public money.

Chairman HALL. All right. Does the gentleman yield back?

Mr. CLARKE. Mr. Chair, before I do that, I wanted to thank Ranking Member Johnson for her steadfast leadership providing me the great opportunity of participating as a freshman Member of this panel. Chairman Hall, you are a true gentleman in every respect in how you have governed this Committee in a fair and balanced way. It has been an honor to serve with you and all of you in this country. Thank you so much.

Chairman HALL. Thank you. Ms. Johnson, I agree with you completely. You are a gentleman. Thank you.

Now, the Chair recognizes Dr. Harris for five minutes.

Dr. HARRIS. Thank you very much, Mr. Chairman.

I want to thank the panel for being here today to review really what the strategy is going forward. I am going to ask for comments on a very particular aspect, and Dr. Zurbuchen and Dr. Pace really, and it leads off what Chairman Walker had said that at some point there is important input from manned missions. But to be honest, a lot of the critical things that we are doing defense-related, weather-related, really there is no manned input necessary. And I am an anesthesiologist. I work in the operating room. The robotic surgery we are doing you literally could do from around the world. You could have the surgeon sitting around the world from where that machine is actually performing an intricate operation with tactile feedback. I mean—and I don't remember the fancy scientific name for it, so you actually feel what the tissues feel like, a lot of inputs that the Chairman indicates that human input actually now is being gained. I mean there are robotics classes and then clubs in their high school. I mean this is to some extent the future.

Given the expense of the redundancy necessary in a manned program and our need to get the most training and research and engineering experience knowledge for the dollars we spend at NASA, isn't it time to say that maybe manned programs should be really

rare and reserved for rare occasions because they just don't deliver the bang for the buck—I am talking about basic science knowledge.

And, Dr. Zurbuchen, your testimony is excellent. I think it points out that we need to know these things and there are other societal benefits. But to the two doctors on the panel, isn't that really the way we ought to be thinking of going if our basic expansion of knowledge with—through a government-funded entity like NASA—and of course preserving defense-related, weather-related, all the other things that we do, is that the way that we should go?

Dr. ZURBUCHEN. My personal feeling is that there is tremendous value over time that has come both from the manned and from the robotic-type missions. I do believe that robotics will have —on the time scale of the next 20 years or so probably if we make predictions, which as you know is always hard, but if you make predictions, will have more economic impact on how we are going to drive our cars, how we are going to fly our planes, and how surgeries are being performed and human space missions. It is my belief, though, that if you go to a time scale of 30 or more years that that prediction is going to be a lot tougher to make. I believe that in many ways, once you put the human in the loop and especially if you go to places where you do not know where you are going, kind of the true exploration, that things happen on the innovation front that really help us uncover aspects of our experience and also aspects of technology that will have tremendous impact in long-term.

The same certainly happened on the Apollo side. It is not the case that even though the examples you are mentioning are truly compelling, there are many aspects to our lives that did come from the human side of NASA as well. So basically, if you asked the question as clearly as you did, should we just kind of forget all about it? I certainly would not subscribe to that kind of recommendation.

Dr. HARRIS. And I want to emphasize not forget it but lower the emphasis a little bit is really—Dr. Pace.

Dr. PACE. Sure. I think first of all you have to make a distinction between sort of science and exploration. I mean NASA is more than just a science agency. It also is an exploration agency. It is a tool of U.S. foreign policy. So it does a whole bunch of things other than just science. If we are just looking at science as defined, say, in the decadal surveys, then it is really straightforward. Okay, robotics systems are what you do. But the reason why you do humans in part is for exploring the unknown, by literally putting people in an unusual or an alien situation, you learn things that you wouldn't learn if you stayed at home.

There is a wonderful example of looking at salmonella viruses and how they have become more virulent in space in zero-g, and these are experiments to be done in a space station, and this means there is a gene sequencing issue. And if we can figure out how to control that, we can have a potential vaccine for salmonella. Okay. That is not something that would ever really have emerged in a ground-based laboratory. It emerges when we put life sciences, people in a very, very different environment to go into the unknown.

Human space flight is probably the most interdisciplinary scientific and technical activity that this country can engage in, much broader than biotech, IT, any of the other particular fields because you really have all fields have to come together to pull off a successful mission. It is incredibly, incredibly hard. But that is where really the benefit is from pushing into the unknown. So I would say as part of your portfolio of activities that humans have to be part of it because they do represent this really challenging interdisciplinary problem that is really unique. And it should be part of our national portfolio because there is nothing that replaces the symbolism, the emotion, the connection that it makes not only to the American people but also to our partners around the world.

The International Space Station is not only an engineering triumph but it also a massive diplomatic triumph that has paid great benefits I think for this country already in terms of building relationships around the world.

So the question for NASA and human space flight is what do you want it to be? What national interests do you want it to serve? If it is only science as defined in the decadal surveys, then I think you can go down a purely robotic path. But I think the vision for NASA is much bigger than just that. It is a science agency but it is also so much more.

Dr. HARRIS. Thank you very much. And I thank the panel and thank the Chairman for the opportunity to serve on the Committee.

Chairman HALL. I have a feeling that General Sega wants to add something. You can't turn a general down.

General SEGA. Well, thank you. I just wanted to add to—the question itself poses one of the key points of our study is that national consensus determining the strategic goals and objectives are important, and from that would flow then the balance and integration perhaps of exploration, science, technology, and aeronautics for NASA.

Another point as—Congressman Walker talked about a report. I just want to clarify. One of our options was to institute an aggressive restructuring program to reduce infrastructure and personnel cost and improve efficiency. We didn't go into any detail of whether that was an option one would choose or how to do it. So thank you very much, sir.

Chairman HALL. I thank you very much. And the gentleman has yielded back.

I want to thank everyone. Thank you for your time of preparation, travel, and presentation. And all the staff here, I want to thank these wonderful staffs that make this world go.

And I would like to ask unanimous consent that as we close today that we close in memory of the life of Gabrielle Giffords on her life and remember the death of Neil Armstrong for a moment of silence. Amen.

We are closed.

[Whereupon, at 12:36 p.m., the Committee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Maj. Gen. Ronald Sega

Questions for Maj. Gen. Ronald Sega
From Chairman Ralph Hall
December 12, 2012 Hearing on
The Future of NASA: Perspectives on Strategic Vision for America's Space Program.

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1. Based on your experience, what recommendations would you give to NASA as it considers realignment of its Centers? Are there examples within the federal government that might provide a model for NASA to consider?

2. What recommendations do you have for improving cross-agency coordination in the realm of the nation's aeronautics and space activities?

3. *Option 4* of the NRC report, recommends reducing considerably the size and scope of elements of NASA's current program to better fit the current and anticipated budget profile. Did the NRC identify any activities currently within NASA's portfolio that might be suited for another U.S. agency or outside government altogether?

4. How can Congress, working with the Administration, correct the mismatch of NASA's missions with future constrained budgets?

5. Legislation has been introduced calling for lengthening the term of the NASA Administrator as a way to help stabilize NASA strategic direction. Your testimony makes it clear that he largest problem is not at the NASA level, it's a problem of national leadership and coming to a consensus between the white house and congress. Would a longer term for the NASA Administrator have an effect?

6. NASA has had some success using enhanced use leasing authorities to bring tenants into underutilized facilities. What changes to the current enhanced use leasing agreements would be necessary so the government could gain more benefits from the process?

Questions for Maj. Gen. Ronald Sega
From Ranking Member Eddie Bernice Johnson
December 12, 2012 Hearing on
The Future of NASA: Perspectives on Strategic Vision for America's Space Program.

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1. What are the criteria for a NASA strategic vision that has staying power? Are risky and ambitious programs a prerequisite to generating national support? If so, can we afford them, both in terms of dollars and risk involved?

2. How can we, as a Nation, achieve a national consensus on NASA's future and the priorities we want it to pursue? As you know, Congress has passed successive NASA Authorization Acts with consensus goals and objectives that Presidents of both parties have signed. What else do you think needs to be done?

3. Your panel's report states that "the full historically demonstrated potential of the aeronautics program is not being achieved given the current levels of funding". Can you provide greater detail on what that potential is and what level of funding the panel feels would enable that potential to be recaptured? How important is a strong NASA aeronautics program to the Nation?

4. Your panel's report says that the lack of national consensus on NASA's missions and budget uncertainties has resulted in the distribution of resources being out of synch with what the agency can achieve in the context of what it has been asked to do.
   - Can you provide examples of NASA programs that are out of synch?
   - Is this a recent occurrence?

5. Your panel's report stresses the need for international cooperation, tied with an understanding that our leadership position depends on partner perceptions that we know the way forward.
   - When one looks across NASA's international programs, including the recent ExoMars situation, do you think the U.S. has been a reliable partner in international space missions?
   - What are the positive lessons learned from successful partnerships, like the International Space Station?

6. The NASA Chief Financial Officer (CFO) is tasked with developing NASA's Strategic Plans. Your panel's report was critical of those plans, citing a failure to identify clear priorities and a transparent budget allocation process. Should the CFO—someone focused on agency finances—be in charge of strategic planning, or should it be done somewhere else?

Responses by The Honorable Robert Walker

Questions for Rep. Bob Walker
From Chairman Ralph Hall
December 12, 2012 Hearing on
The Future of NASA: Perspectives on Strategic Vision for America's Space Program.

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1. Lacking a major national imperative, such as what existed during the Cold War, and considering the current strains on resources and the nation's attention on crises at home and abroad, what role should Congress play in reaching a consensus on the shape, size and direction of an exciting and credible space strategy?

2. How can Congress work with the Administration to correct the mismatch of NASA's missions with future constrained budgets?

3. NASA has had some success using enhanced use leasing authorities to bring tenants into underutilized facilities. What changes to the current enhanced use leasing agreements would be necessary so the government could gain more benefits from the process?

4. In your testimony you emphasize increasing public-private partnerships. But, recently there have been some public-private partnerships that have not ended well, such as *Solyndra*. And just two weeks ago we learned about battery maker *A123* which filed for bankruptcy after it received $249 million in federal money to spur manufacturing of batteries. Now it is being sold to a large Chinese firm. Given that the vast majority of funding for NASA's public-private partnerships is taxpayer money how can the government guard against creating another *Solyndra* or *A123*?

5. In your testimony you say NASA can extend its reach and find new financial resources by opening doors wide to collaborative programs. NASA has been trying that approach with the commercial crew program, but it is primarily funded by taxpayers with about 90 percent federal money. Yet the government has relinquished title to the designs and the intellectual property. In your opinion why haven't commercial companies contributed a higher percentage of the cost of these systems in light of such generous terms, and what can be done to reduce the government's contribution to less than 90 percent?

6. Your testimony mentions sponsorship opportunities as having potential to leverage more funds to do missions, for instance, the Mars Rover. Can you provide us with examples where a sponsorship model has worked for the federal government?

Responses by The Honorable Marion C. Blakey

Questions for The Honorable Marion Blakey
From Chairman Ralph Hall
December 12, 2012 Hearing on
The Future of NASA: Perspectives on Strategic Vision for America's Space Program.

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1. Lacking a major national imperative, such as what existed during the Cold War, and considering the current strains on resources and the nation's attention on crises at home and abroad, what role should Congress play in reaching a consensus on the shape, size and direction of an exciting and credible space strategy?

2. How can Congress, working with the Administration, correct the mismatch of NASA's missions with future constrained budgets?

3. Your testimony recounts examples of NASA having endured previous periods of budget uncertainties, even in the midst of developing expensive new capabilities such as Shuttle. What priorities should Congress focus on in the current period of uncertainty to ensure NASA retains the important capabilities?

4. From an industry perspective, what are we at risk of losing if the government fails to reach consensus on NASA's strategic direction?

5. Given the end of the shuttle program and the lack of clear strategic direction, how does the uncertainty threaten our industrial base; can you characterize the capabilities that are at risk? Perhaps give examples?

6. Given the importance of maintaining our aerospace industrial base, about how much of it is attributable to NASA, and if NASA reduces its spending, what happens to the people who build these systems? To what degree can the Defense Department and civil or commercial customers absorb these people and facilities?

Questions for The Honorable Marion Blakey
From Ranking Member Eddie Bernice Johnson
December 12, 2012 Hearing on
The Future of NASA: Perspectives on Strategic Vision for America's Space Program.

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1. Does having a clear strategic vision for NASA affect the decisions made by the aerospace industry? If so, how?
    - What are the implications for the industry of not having a clear vision for NASA?

2. The NRC panel's report states that "*the full historically demonstrated potential of the aeronautics program is not being achieved given the current levels of funding*".
    - Can you comment on whether you agree with the panel's conclusion and estimate what level of funding is needed in order to recapture that potential?
    - How important is it for NASA to maintain a meaningful and robust aeronautics R&D program?

Responses by Dr. Thomas Zurbuchen

Questions for Dr. Thomas Zurbuchen
From Chairman Ralph Hall
December 12, 2012 Hearing on
The Future of NASA: Perspectives on Strategic Vision for America's Space Program.

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1. How can Congress, working with the Administration, correct the mismatch of NASA's missions with future constrained budgets?

2. Knowing the importance of maintaining our scientific research pipeline, how much of that is driven by NASA? If NASA reduces its spending, to what degree can other agencies such as the Defense Department and commercial customers absorb these people and facilities?

3. Your testimony highlights the importance of maintaining the pipeline of engineers and scientists to ensure that we continue to innovate in the future. What are your recommendations for a program that provides opportunities to our graduate and post-doctoral students to the benefit of future U.S. leadership in space?

4. What is the appropriate ratio of Research & Analysis funding as part of NASA's overall science strategy? In your opinion, should funding be carved out to ensure R&A programs endure budget shortfalls as part of an overall strategy?

Questions for Dr. Thomas Zurbuchen
From Ranking Member Eddie Bernice Johnson
December 12, 2012 Hearing on
The Future of NASA: Perspectives on Strategic Vision for America's Space Program.

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1. Your prepared statement discusses a high priority for NASA in "growing innovative activities and an entrepreneurial mindset in our science and engineering communities", including focusing on disruptive technologies. NASA's Space Technology Program (STP) was established, in part, to stimulate the development of game-changing technologies. Were you envisioning STP to conduct this high priority work? If so, how effective has this Program been in generating the innovation mindset that you state is so important? If not, who should?

2. In your opinion, what scientific discoveries or technological breakthroughs would dramatically change the current and future path of NASA?

Responses by Dr. Scott Pace

U.S. House of Representatives
Committee on Science, Space, and Technology

Questions for the Record

"The Future of NASA: Perspectives on Strategic Vision for America's Space Program"

Wednesday, December 12, 2012
9:30 a.m. - 12:30 p.m.
2318 Rayburn House Office Building

Questions for Dr. Scott Pace,
Director, Space Policy Institute, George Washington University

Questions Submitted by Rep. Ralph Hall, Chairman

1. *Option 4* of the NRC report recommends reducing considerably the size and scope of elements of NASA's current program to better fit the current and anticipated budget profile. In your opinion, are there activities currently within NASA's portfolio that might be better suited for another U.S. agency or outside government altogether?

   Response:

   There are no easy or obvious answers to this question. All of NASA's major activities have congressional authorization and support a diverse array of worthwhile missions. The question is that, if forced to reduce the size and scope of NASA's current programs, what priorities should apply? In my opinion, NASA should prioritize those activities that uniquely serve U.S. national and international interests, and which cannot or should not be done by other agencies or outsourced to the private sector. The top priority should be a steady program of human space exploration and development, supported by scientific and technical activities, in which the United States is a global leader in concert with international and private sector partners. This would include life science investigations and utilization of the International Space Station, as well as the development of systems for human access to space that are necessary for such utilization. Next, I would give priority to being an international leader in the major scientific themes of space-based investigations in planetary science, Earth science, heliophysics, and astrophysics. Finally, I would seek to support aeronautics and education and reduce the fixed costs of NASA's aging infrastructure across its field centers. Technology development and education activities should be strongly aligned with mission needs, both near- and long-term, and standalone activities should be minimized.

   In theory, it is possible to imagine the creation of a National Climate Service at NOAA, analogous to the National Weather Service to conduct "exquisite" on-going climate observations while NASA retained responsibility for creating pioneering sensors. It is also possible to imagine aeronautics research responsibility being shifted to the Department of Transportation. It is even possible to imagine the National Science Foundation taking on greater responsibility for peer-reviewed scientific missions in space. However, these agencies are unlikely to be able to afford the additional budgetary burden and thus the realistic answer is

likely to be that fewer of these activities will occur if NASA's budget remains flat or is reduced.

However, there is no other agency of the Federal Government in which it is reasonable, or even possible, to imagine taking on greater responsibility for human space exploration and development. This is "the" core function of NASA, the single overriding rationale for the creation of the agency a half-century and more ago. This is the activity which must be strongly supported with both stable policies and stable budgets, if the United States is to continue to be a leader in space.

2. How can Congress, working with the Administration, correct the mismatch of NASA's mission with future constrained budgets?

Response:

Among the most helpful things the Congress could do is ensure that resources that are provided for authorized programs are in fact used fully for those programs. Funds for the Space Launch System, for example, should not be encumbered by termination liability until and unless the Congress intends to terminate the program.

Second, Congress can press for a revision or update of the National Space Policy on civil space exploration to enable a practical architecture for human exploration beyond low Earth orbit, i.e., missions in cislunar space and, most importantly, to the lunar surface. The lack of a practical architecture, understood by potential international partners, makes other programmatic and budget decision more difficult than they need to be.

Third, Congress can help reduce risk and waste by pressing forward to downselect a single provider for "commercial crew" services to the International Space Station and to bring development under standard contract clauses that apply to other development programs and service purchases. The "commercial crew" program could be transferred from the Exploration account to the Space Operations account and more accurately designated as "ISS Logistics and Support" in combination with "commercial cargo" services and payments to Russia for launches.

3. You point out that since the cancellation of Constellation we now have a situation where systems being built for low Earth orbit have little in common with systems being built for beyond low Earth orbit. Does this strategy of following separate and distinct development paths drive up overall costs, and can it have an adverse effect on crew safety?

Response:

Having multiple development paths that are not well integrated into a long-term architecture drives up costs by duplicating fixed costs and spreading thin demand over fewer flights. This need not necessarily have an adverse effect on crew safety, but it makes it more difficult and expensive to build up confidence in system reliability. There is a tension between lowering overall risk by having dissimilar systems with independent failure modes and increasing individual system risk with lower levels of flight experience.

The *Columbia* Accident Investigation Board made a strong recommendation to reduce dramatically the probability of crew loss in the new generation of human-rated launch vehicles.

Ten years later, that recommendation seems to have been forgotten. The Constellation program drew upon high flight heritage parts and components in a closely integrated architecture for access to both low Earth orbit (LEO) and the lunar surface, and that also provided a clear "on ramp" for private cargo, and eventually crew, services to LEO. Those new, private services were intended to accumulate flight heritage that, over time, would hopefully demonstrate safe operations at less cost compared to heritage systems. Today, we do not have an accepted architecture for moving beyond low Earth orbit, and we are reliant on private developments for what is arguably a strategic national capability – human access to space. As things stand now, for many years to come we will be reliant on systems with low flight heritage and low flight rates that will delay progress on improving crew safety and that offer little or no extensibility for missions beyond LEO.

4. Given the importance of maintaining our aerospace industrial base, about how much of it is attributable to NASA, and if NASA reduces spending, what happens to the people who build these systems? To what degree can the Defense Department and civil or commercial customers absorb these people and facilities?

Response:

Using Aerospace Industry Association figures for 2012, NASA accounted for less than 10% of all aerospace revenues. Space as a sector accounted for about 20% of all aerospace revenues. Thus, from a pure revenue and employment standpoint, the Defense budget has a much greater impact. However, this fails to account for the uniqueness of NASA missions and the quality of the work it enables. Human space activities are among the most interdisciplinary of activities, requiring skills from every field of technical endeavor. Their successful accomplishment requires a degree of systems engineering skill found only in the most complex and demanding programs. By seeking to conduct human (and robotic) missions that have never been done before, civil space missions drive innovation and provide a demand for the most creative possible technology. So while it is possible in theory, to redirect, retire, and retrain the NASA civil service and contractor workforce into other fields, their unique expertise and contributions would be lost.

Questions Submitted by Rep. Eddie Bernice Johnson, Ranking Member

1. What are the criteria for a strategic vision that has staying power? Are risky and ambitious programs a prerequisite to generating national support for NASA? If so, can we afford them, both in terms of dollars and risk involved?

   Response:

   A strategic vision for NASA should be one that is closely aligned with enduring national interests and thus can have necessary long-term sustainability. For example, we do not debate whether or not to have a Navy, even though there are debates as to exactly what missions the Navy should undertake and what level of naval forces we can afford. Similarly, we do not debate whether or not have an unmanned scientific space program even while dealing with serious programmatic challenges and evolving priorities of the scientific community. *The primary question for NASA's strategic vision is the existential one of whether to engage in human space exploration and, if so, how best to conduct it.* As discussed in written testimony, I believe human space exploration should be part of American "soft power" in support of geopolitical interests in a post-Cold War world.

   Being "risky" or "ambitious" per se are not required characteristics for national support as much as having NASA programs that are purposeful and meaningful. As the Columbia Accident Investigation Board (CAIB) recommendations implied, if we are going to risk human life in space, then we should be seeking potential gains commensurate with those risks. We should be pursuing goals that support our nation's strategic interests. Merely going to and from low Earth orbit or conducting a one-time mission to an asteroid or even Mars are examples of missions which fail this key test. On the other hand, answering "grand challenge" questions such as whether or not humans have a future beyond the Earth, and if so, what cultures they will represent and values they will hold, does have the necessary level of importance to justify sustained exploration efforts. In terms of affordability, there is no reason to have NASA expenditures in excess of 4% or the federal budget as occurred during the early 1960s. At the same time, increasing the NASA budget to $19 billion would represent only 0.5% of the federal budget. A stable level of NASA funding is quite affordable, but only if it is used to support important national objectives. If not, then even the current modest levels will not be acceptable over time.

2. How can we as a Nation achieve a national consensus on NASA's future and the priorities we want it to pursue? As you know, Congress has passed successive NASA Authorization Acts with consensus goals and objectives that Presidents of both parties have signed and for which appropriations have been provided. What else do you think needs to be done?

   Response:

   A requirement for a national consensus in which all Americans agree on a particular course of action is not likely to be realistic. National consensus is rarely found in any matter of national importance. What is necessary is for there to be a close alignment, approaching a consensus, between the White House and Congress in order to create the policy stability necessary for challenging, long-term space missions. Securing a close alignment typically requires attention to three factors: policy, process, and people. National Space Policy and Presidential Budget Requests should be changed to support a more practical program of human space exploration; one that also provides more opportunities for international and private sector participation,

while at the same time preserving the authority, responsibility, and accountability for the expenditure of public funds that is expected of a Federal agency. Second, an international architecture for human space exploration should be adopted, building on the work of the International Space Exploration Coordination Group. Finally, the most senior leaders at NASA, who are confirmed by the Senate, need to accountable for implementing and executing laws passed by Congress and signed by the President. There are analogous challenges with NASA's unmanned science programs, but those are less immediately dire than the current state of human space flight.

3. In your prepared statement, you discuss "possible credibility issues and complications for US efforts to expand international cooperation in space."
   - What do you see as actions that would restore the credibility?
   - What does a clear strategic vision for NASA mean with respect to our partnerships in the international community?
   - How do our international partners view the existing strategic vision for NASA?

   Response:

   Trust is built in layers and derived from actual experience. This has been the case on the International Space Station and it will be true of any efforts to go beyond the Station. A helpful first step would be to ask potential international partners, both long-standing and new spacefaring states, what they would like to work on in explorations beyond low Earth orbit. Next, the United States could show that it was listening by coordinating its technology and development programs with potential partners in such a way as to ensure all parties have meaningful roles commensurate with their capabilities and resources.

   The key desire of international partners is for predictability and stability so they can make their own plans in support of their own national interests. In my view, potential partners do not see the existing strategic vision as credible or stable, because key aspects (e.g., capability-driven evolution) of the vision are not clearly aligned with understandable U.S. interests. Further, there does not seem to be room for meaningful international cooperation with the displacement of the Moon as a focusing goal. Mars is too remote to serve as a unifying goal for any present-day budget, and a mission to an asteroid almost self-evidently disallows any meaningful degree of international participation. The willingness to test the European ATV for the Orion Service Module is a helpful, albeit limited step toward international credibility as it supports the ISS. Unfortunately, this comes at the cost of removing from the Glenn Research Center its previously assigned responsibility to develop the Service Module, and a consequent loss of needed development experience at that Center and within the United States. I would have preferred cooperation with Europe on the proposed Liberty vehicle as being of more long-term strategic value to both the United States and our partners.

4. During the hearing you spoke of the fact that with regards to support of the space program, Americans have an interest in life, in people, Earthlike planets, and securing a personal connection and participation. What actions can Congress and the Executive Branch take to ensure that NASA's strategic direction taps into this interest and desire to participate?

   Response:

   There are three things that can be done reflect public interest in question of life in space and having a more personal connection to experiences in space. The first is to have a human space

exploration effort that is actually engaged in determining what kind of future humanity might have in space. Are privately supported space settlements possible? Or will space be like Antarctica – mostly government activities with some tourism. Will the United States be the dominant or leading power in cislunar space, or will leadership pass to others (e.g., China)?

The second is for NASA to support, within its authorized missions, efforts aimed at increasing public awareness and participation in human and robotic discoveries. NASA has a Participatory Exploration Office that is experimenting with different forms of public outreach. A key consideration for such efforts is that they make meaningful mission contributions and not merely be "public relations" or agency advertising. Public communications is important, but public participation and engagement are more difficult and demanding.

Finally, NASA should work with other agencies, as it is doing with the FAA, to enable the growth of a safe and competitive space transportation sector that can create private sector opportunities for space tourism and commerce. This has the potential for greatly increasing the scale and scope of direct public experience with space flight. However, private markets will ultimately determine the success of such ventures; NASA should not play an "industrial policy" role in which it picks "winner and losers" other than as a direct result of securing public goods and services. In other words, NASA can help enable the emergence of space tourism, but should not try to substitute its judgment for market competition in determining when space tourism would become viable.

5. You said that if the ISS is not well supported, then "anything else is kind of meaningless." You also voiced concern that ISS utilization would go down if a reduction in crew size were made in response to inadequate provisioning of the ISS. What ISS goals and objectives would ensure that this unique laboratory is accorded the proper priority in NASA's strategic direction?

   Response:

   The ISS has reasonable goals and objectives and its utilization is a priority for NASA. Unfortunately, what has been missing is attention to ensuring robust access to the facility. The cancellation of the Ares 1 was problematic for several reasons, only one of which was that it left NASA without an alternative means or access to the ISS in the event of delays or shortfalls in the "commercial cargo" program. Should there be further delays in providing adequate ISS upmass, a reduction in crew size may become necessary. This would reduce ISS utilization effectively to zero, as crew time would be dedicated to maintaining the facility.

   More seriously, should there be a "bad day" on the Station, this would not only be a disaster for NASA, but also an end to the near-term market for the "commercial crew and cargo" companies. It would be very difficult to restart a U.S. human space flight effort without the pull of the ISS partnership and it is unlikely that private firms could recreate a human spaceflight capacity solely with non-U.S. government demand. Thus, improving the robustness and diversity of support to the ISS is crucial to utilization, our current international partners, and the future of U.S. human space flight, both public and private.

6. The NASA Chief Financial Officer (CFO) is tasked with developing NASA's Strategic Plans. The NRC panel's report was critical of those plans, citing a failure to identify clear priorities and a transparent budget allocation process. Should the CFO – someone focused on agency finances – be in charge of strategic planning, or should it be done somewhere else?

Response:

The short answer is no, the CFO's office should not be in charge of strategic planning. The CFO should, in my opinion, be responsible for the integrity and accuracy of NASA finances, not the development of strategic plans outside of that competence. There should be a clear organizational separation between the functions of authorizing checks to be paid, and accurately accounting for those checks. Co-mingling those functions in a single office is an excessive concentration of power that can undermine internal agency checks and balances, e.g., those that should exist between the field centers and the mission directorates. In my experience, the placement of strategic planning, budget planning and programming, and evaluation functions in an Office of Program Analysis and Evaluation -- *that was entirely separate from the CFO* -- worked well. There can be frictions as a result of this separation, but the benefits to transparent agency governance made it worthwhile. This problem of concentrated power is not new and occurred in the past with the old NASA Comptroller function, which is in part why PA&E was created. It is unfortunate that NASA disestablished and broke up PA&E, and I would advocate its restoration if the NASA Administrator was willing to use it properly.

Appendix II

Additional Material for the Record

SUBMITTED STATEMENT FOR THE RECORD BY REPRESENTATIVE JERRY COSTELLO

The NASA Authorization Act of 2010 states that "The National Aeronautics and Space Administration is and should remain a multi-mission agency with a balanced and robust set of core missions in science, aeronautics, and human space flight and exploration."

Last week, a National Research Council (NRC) panel found that NASA's ability to sustain that balanced portfolio is in jeopardy. This should not be a surprise. As this Committee has reiterated on multiple occasions, for the past several years, NASA has been underfunded.

There is a mismatch between what we expect NASA to do and how much we fund it.

This is unfortunate, because NASA is a critical part of the Nation's research and development enterprise, as well as a worldwide symbol of American technological prowess and the global leader in space and aeronautics. That status is no longer assured.

More troubling is the NRC panel's conclusion that "The approach to and pace of a number of NASA's programs, projects, and activities will not be sustainable if the NASA budget remains flat, as currently projected."

I understand that we are in tough economic times. But I hope that this hearing will illustrate how NASA provides a sizeable return on the taxpayer's investment through its balanced portfolio. So I am eager to hear from our witnesses on how we can ensure that NASA maintains its leadership in space science, aeronautics research, and human space exploration.

In my final days as Ranking Member of the Space and Aeronautics Subcommittee, let me say that over the years, I have seen NASA do great things supported by a dedicated workforce and able contractors.

If we in Congress do our part, a flight test of the Orion Capsule in 2014, initial test of the Space Launch System in 2017, launch of the James Webb Telescope in 2018, and completion of critical R&D in support of NextGen by 2018—among other important tasks—are all possible and NASA will continue reaching for the stars and helping to improve life here on Earth.

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