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Subcommittee on Space and Aeronautics Hearing

"NASA's Strategic Direction"

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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

[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]

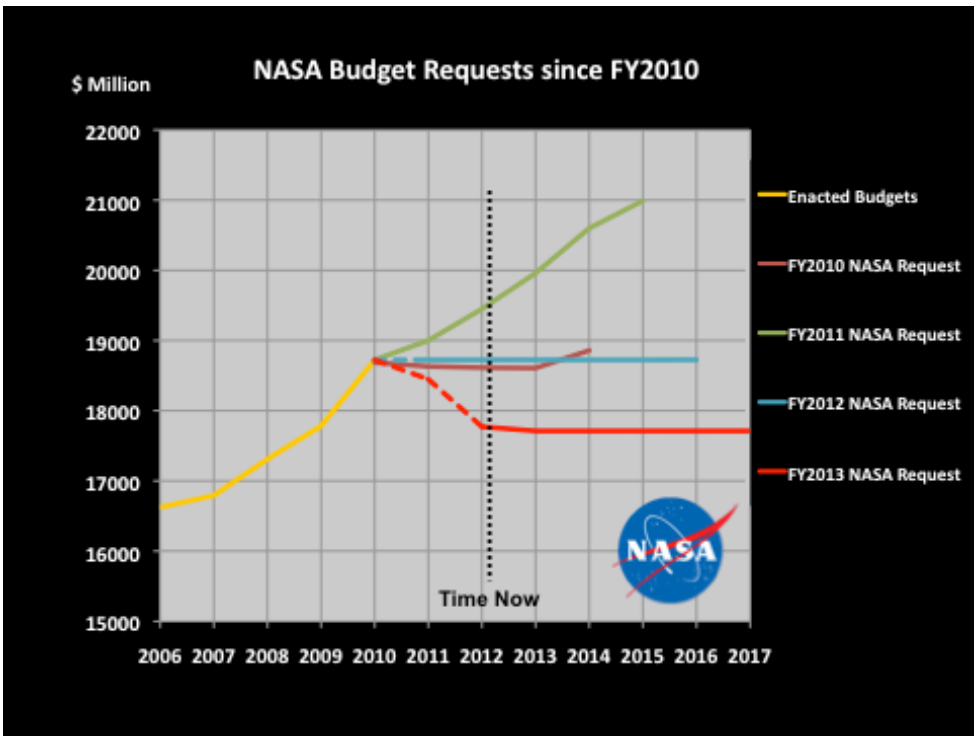

Figure 1 – NASA Budget Requests since FY 2010

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.

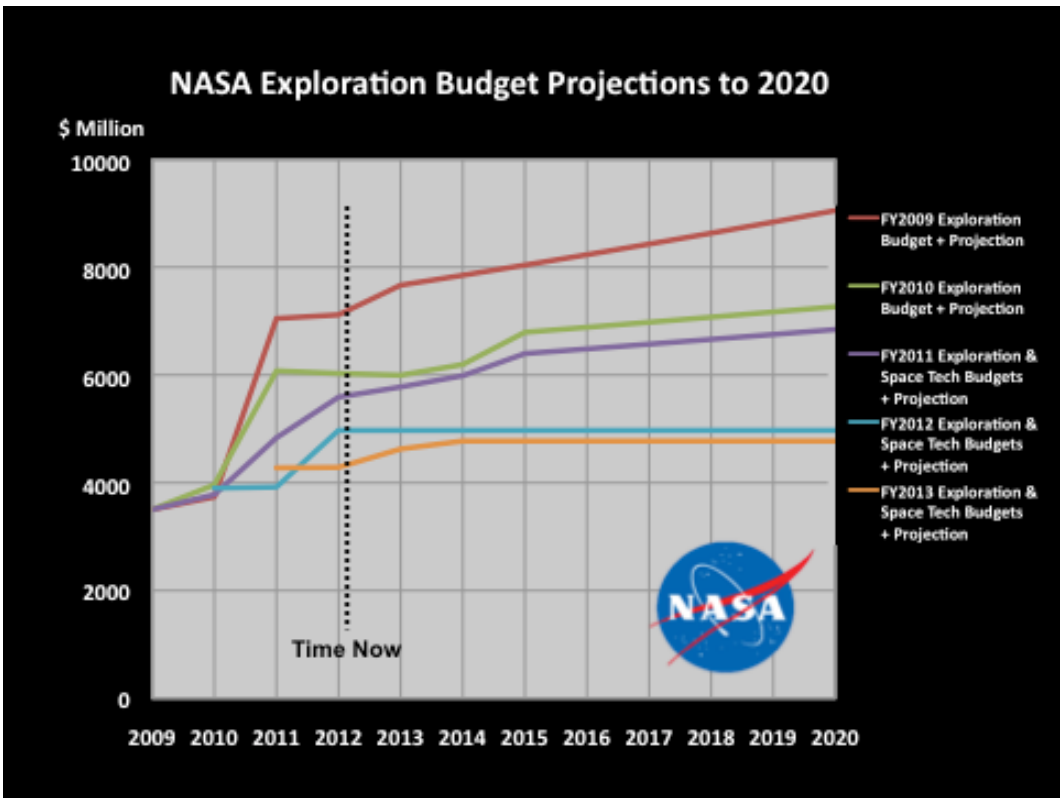

Figure 2 – NASA Exploration Budget Projections

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.

<u>Capability-driven</u>

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.

<u>Geopolitically-driven</u>

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.

[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.

[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.

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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.