**Statement of**
**Christopher F. Chyba**

**Prepared Testimony to the**
**Subcommittee on Science and Space**
**Committee on Science, Commerce, and Transportation**
**United States Senate**
**May 18, 2011**

# Contributions of Space to National Imperatives

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## Introduction

Chairman Rockefeller, Subcommittee Chairman Nelson, Ranking Member Boozman, members of the Subcommittee, thank you for giving me the opportunity to testify on this important subject. In the summer and fall of 2009, I had the honor and responsibility of serving on the Review of U.S. Human Spaceflight Plans Committee (sometimes informally called the "Augustine Committee" after its chair, Norm Augustine), which issued its 156-page final report in October 2009.[1] The committee formally ceased to exist on December 1, 2009.[2] Therefore my testimony today does not (and cannot) represent the views of the Human Spaceflight Committee. I am speaking solely in my personal capacity. Of course, my views are informed by the intensive data-gathering and analysis that our former committee undertook in summer 2009.

The testimony that follows begins by briefly reviewing our committee's mandate, and a few of its programmatic findings and options. A second section presents my own views of the most important characteristics of our report, those that go well beyond programmatics. Media accounts of the report naturally highlighted its programmatic

[1] Norman R. Augustine, Wanda M. Austin, Christopher Chyba, Charles F. Kennel, Bohdan I. Bejmuk, Edward F. Crawley, Lester L. Lyles, Leroy Chiao, Jeff Greason, and Sally K. Ride, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, October 2009.
[2] Electronic mail, subject "Committee Termination," from Philip McAlister at NASA to members of the U.S. Human Spaceflight Plans Committee, December 2, 2009.

options and implications, yet I believe that the report's most important findings are those framing an overall approach to human spaceflight regardless of details about launch vehicles or crew capsules. The final section of my testimony brings this discussion to bear on the situation today.

I close this introduction with a personal remark. I am a planetary scientist who has been fortunate to be directly involved in the spacecraft exploration of the outer planets, in NASA mission planning, in the search for life in our Solar System, and in the scientific Search for Extraterrestrial Intelligence (SETI). Half of my academic appointment is in astrophysics; the other half is in international affairs and, in particular, nuclear and biological weapons nonproliferation and arms control. I believe that human spaceflight has relevance to both science and security, but I do not consider it to be central to either endeavor. Nonetheless, I support human spaceflight and favor our long-term expansion into the Solar System. One of the ultimate objectives of hearings like this, it seems to me, is to help ensure that the United States, and human civilization, has that future in space.

**The Human Spaceflight Committee: Mandate and Programmatic Findings**

The Human Spaceflight Committee was established to review NASA's human spaceflight Program of Record and to offer possible alternatives. Its mandate was to provide options, rather than make recommendations, for different possible exploration architectures. This mandate did not include an evaluation of the value of human spaceflight vs. robotic exploration.

The Committee examined NASA's existing architecture for going beyond low-Earth orbit--the Constellation program--and concluded that Constellation could not be

executed at planned budget levels. The reasons for this were primarily budgetary. These included that Constellation's Exploration Systems Architecture Study (ESAS) of 2005 assumed that human spaceflight funding would increase until reaching a steady state of about $10 billion per year. But the first post-ESAS budget, the FY 2007 budget, provided significantly lower funding for the Ares I rocket and the Orion crew vehicle than ESAS had anticipated. Pushing programs out into the future always increases costs. Differences between anticipated and actual budgets, plus technical problems in the Ares I and Orion programs, had significant impact. The FY 2009 budget was lower than that anticipated by ESAS by at first $1 billion per year, and then lower with a growing disparity that reached $2 billion per year in the steady state. The FY 2010 President's Budget Submittal was lower still, anticipating a final steady state level of funding of about $7 billion per year—some $3 billion below the annual $10 billion against which ESAS had originally planned.

Moreover, it was intended that Shuttle would complete its final flight in 2010, and that the International Space Station (ISS) program would be terminated in early 2016, with corresponding savings becoming available for Constellation. But the ISS termination itself was not budgeted. Yet termination would have to entail the safe de-orbiting of this 350 metric ton structure, requiring either the design, construction and flight of a new de-orbit module to accomplish this task, or the piecemeal de-orbit of the structure via disassembly.[3] Taking all this into account, the Human Spaceflight Committee concluded that under the FY 2010 funding profile, the Constellation program would at the least be greatly stretched out in time. The planned heavy-lift vehicle (Ares

[3] The Committee requested an independent assessment of this task, and found projected costs of $2 billion or more, depending on the method of de-orbiting required. Augustine et al., *Seeking a Human Spaceflight Program*, p. 54.

V) would not be available until the late 2020s, and lunar return could not occur until well into the 2030s, if at all. In short, the Constellation program was not executable at its existing budget.

The Committee considered a variety of integrated scenarios: Constellation and variations thereof; less demanding returns to the Moon; and a scenario of increasing deep-space capability that it called "the flexible path." Five principal integrated options (with sub-options) were evaluated against twelve metrics, including science knowledge, technology innovation, economic expansion, workforce impact, public engagement, and mission safety.[4] The flexible path had the budget profile advantage of not requiring the simultaneous development of both heavy-lift capability and lunar-landing vehicles. But no architecture would provide missions beyond LEO until close to 2030 under the FY 2010 budget profile.

In historical context, this is not surprising. A plot of the human spaceflight annual budget (in FY 2009 dollars) through time shows a sustained peak during the Apollo years in the 1960s of nearly $20 billion per year. That budget is now, and has been for nearly two decades, at a level of half this or less. The Committee concluded that sending astronauts beyond LEO in the 2020s would require ramping up to a steady-state augmentation of NASA's budget by some $3 billion per year.

[4] A Mars-first scenario had also been considered, but was evaluated to be so expensive that it did not make sense to examine it out to this level of detail. The five options considered (along with sub-variants) were a baseline case, founded on the Constellation program, a case in which ISS was extended and the development of Ares I was foregone, lunar-oriented strategies, and flexible-path strategies. The twelve metrics used for evaluation were exploration preparation, technology innovation, science knowledge, expanding and protecting human civilization, economic expansion, global partnerships, public engagement, schedule and programmatic risk, mission safety challenges, workforce impact, programmatic sustainability, and life-cycle cost. See Augustine et al., *Seeking a Human Spaceflight Program*, Chapter 6, "Program Options and Evaluation."

**Beyond Programmatics**

I believe that the most important contribution of the U.S. Human Spaceflight Committee report lies neither in its finding that the Constellation program was not executable at its existing budget, nor in its options for future programs, but in the framework it suggested for the future of human spaceflight. This framework provides the lens through which I view the current situation.[5]

First, the report emphasized that the choice facing us is one of *goals, not destinations*. The debate over human space flight should not begin as an argument over destination--for example, "Should we go back to the Moon?" or "Should we go to Mars?" Framing the discussion this way risks choosing a destination first, then searching for reasons to justify that choice. At least in part, that is what went wrong with the International Space Station, a destination in low-Earth orbit (LEO) that is still searching to explain its purpose.[6]

That the Station's purpose was difficult to identify is demonstrated, I believe, by the Constellation program's intention to simply terminate Station in early 2016—almost immediately after its completion. Dropping the ISS into the ocean upon completion suggests that it was viewed as no more than a gigantic white elephant. But such a plan makes some sense, in a disheartening way, if one's destination had once been the Station itself, but now one's destination has shifted, say, to the Moon. (Even in this context the plan is questionable, since the diplomatic price that would have been paid with our

[5] The discussion in this section draws, in part, on a McClatchy-syndicated op-ed the author published in late November 2009. See, for example, Christopher Chyba, "Report Provides Roadmap for Human Space Flight," *Cleveland Plain Dealer*, November 29, 2009, available at http://www.cleveland.com/opinion/index.ssf/2009/11/report_provides_roadmap_for_hu.html.

[6] "*Because NASA does not have a compelling vision for how it will use the ISS, many American citizens do not have a clear idea of what it is for."* Augustine et al., *Seeking a Human Spaceflight Program*, p. 56. Italics in the original.

Station partners would have been steep, and this would have damaged our prospects for future international cooperation in lunar return.)

Instead, the Human Spaceflight Committee report argued that we should decide on our goals for human space flight, and then have destinations flow from these goals. The committee concluded that human space flight serves a variety of national interests--and certainly inspiring the next generation, furthering national security, driving technology innovation, and other areas are important among these. But sending human beings *beyond low-Earth obit*, with the enormous expense and long timelines that this entails, does not make contributions to these areas that are so unique or cost effective that they in themselves justify the decision to go beyond LEO. Rather, sending humans beyond low Earth orbit has as its fundamental goal charting a path for human expansion into the Solar System. This is ambitious, but if this is not our goal, we'd best just restrict ourselves to destinations in LEO. Human expansion into the solar system is a goal worthy of a great nation working in concert with other space powers. Choosing this as our long-term goal, while trying to maximize spaceflight's contributions to all areas of society as we proceed, provides the context for making decisions about our next steps. And it also embraces the ISS as a means to an end rather than a destination that we've left behind.

Second, the report insists on *scientific integrity*. Each option presented for consideration was examined for its impact on science, and all else being equal options that did a better job furthering science were rated more highly. But human spaceflight should not be justified with exaggerated claims about its scientific payoff. Exploration with astronauts can have significant scientific benefits in several areas beyond the tautological justification of studying what happens to humans in space. As was

emphasized by scientists' testimony to the committee, astronauts have a tremendous advantage over robot spacecraft when it comes to field geology in particular. The ability to pick up a rock, turn it over, expose a fresh surface with a hammer and then use geological expertise to decide whether to move on or instead to "dig in" and examine the current site in detail is a human capability that far exceeds anything robot rovers can currently do. In a similar way, the ability to service and repair space observatories that face unanticipated problems favors the astronaut over the robot.

But astronauts are also far more expensive than robot spacecraft or rovers, and have their greatest advantage in the most complex environments and circumstances. Mars is the most complicated surface environment we will face in the foreseeable future, so it is where astronauts will provide the greatest advantage. But it will be decades before humans walk on that world—if we are lucky—and for most other science in space, humans often get in the way.

Moreover, if NASA's space science budget is not protected, it could be raided to fund cost overruns in the human program. Human spaceflight, if it is to be justified and sustained, needs to be aligned with national priorities. Were key space-based research to be cut to fund human spaceflight, human spaceflight would be put into opposition with those priorities. This would serve neither science nor the future of human spaceflight well.

We live in a time of extraordinary discoveries about outer space. We have learned that early Mars had standing liquid water on its surface, and that the resulting sedimentary rocks are still accessible. These are the kind of rocks that can contain information about the early martian environment, or even microfossils should life ever

have existed on that world. We've learned that there are many other ocean worlds in our Solar System—moons of the outer planets that host liquid water oceans beneath their ice covers that are as big as our own. We've learned that solar systems are common, and that the arrangement of planets in our own is but one of a vast array of possibilities. And we've learned that most of the mass-energy of the Universe is not made up of the kind of matter we are familiar with here on Earth—and that we don't quite know what this more exotic mass-energy is. Human spaceflight should be an ally in, and certainly not an opponent of, these momentous discoveries.

Third, the Human Spaceflight Committee report called for the government's space agency to concentrate on the hardest technological problems associated with our goals in space flight. For the rest, including sending astronauts into low-Earth orbit, *the commercial sector should play a bigger role.* The commercial sector should "fill in" behind NASA, while NASA spearheads exploration out into the Solar System. In fostering a robust commercial sector, NASA's role would include funding, in a disciplined way, the development of capabilities by a number of commercial actors, developing the technologies to underpin future exploration, and providing an ongoing market pull for the commercial sector by providing destinations—whether this is the ISS or destination projects, such as the development and implementation of potentially game-changing capabilities such as fuel depots in space.

Fourth and finally, the Committee report called for *budget and schedule reality.* The report argued that the budget then foreseen for human spaceflight—$99 billion over ten years—would not allow NASA to do anything beyond low-Earth orbit. NASA could afford to pay for the new rockets and crew vehicle that would replace the space shuttle

and make it possible to journey outward, but not for systems to land on the Moon or for operations on a path to take astronauts to asteroids or to fly around Mars. The report suggested that in order to do both—to develop the new systems and to fly them to destinations beyond low-Earth orbit—would require an increase in NASA's budget of around $3 billion per year.

A problem forever confronting NASA is that it seemingly can have either the budget to develop a new human spaceflight architecture, or it can have the budget for ongoing astronaut operations—but not both. To afford to develop a major new launch system, NASA has to stop flying. This is the current budget dilemma in a nutshell, and the ultimate reason for the upcoming "gap" in U.S. launch access to the ISS. Indeed, to develop Constellation, NASA planned both to stop flying the Shuttle and to terminate the ISS.

You might also notice that the Human Spaceflight Committee's report contained few inspiring artists' conceptions of our dramatic future with human explorers in space. Some past reports have been full of pictures of rocket launches, space cities, and astronauts with rocket packs flying all over. I respect those reports' optimism, and want to share it. But there have been too many glorious images of our exciting future in space unmatched by the budget for a realistic path to that future.

**Current Issues**

The NASA Authorization Act of 2010 declares that "The long term goal of the human spaceflight and exploration efforts of NASA shall be to expand permanent human presence beyond low-Earth orbit and to do so, where practical, in a manner involving

international partners."[7] At this highest level, and I believe in many details as well, the 2010 Authorization Act is consistent with the sense of the Human Spaceflight Review Committee's framework.

An important objective identified by the Authorization Act is to "sustain the capability for long-duration presence in low-Earth orbit, initially through continuation of the ISS . . . and through assisting and enabling an expanded commercial presence in, and access to, low-Earth orbit, as elements of a low-Earth orbit infrastructure . . . ."[8] The bill embraces the development of commercial cargo (Commercial Orbital Transportation Services, COTS) and crew (Commercial Crew Development, CCDEV) capabilities. There will always be arguments over relative and absolute levels of funding, but the vision in the Authorization bill of LEO becoming an economic zone (from the point of view of human spaceflight; of course it is this already with respect to unmanned satellites) sustained by government activities (e.g. servicing ISS, development of new capabilities such as fuel depots) but with increasing commercial opportunities, provides our best chance at bringing costs down and creating a vibrant human spaceflight future in low-Earth orbit. The COTS model in which NASA pays the commercial providers by milestones, rather than in a cost-plus manner, already suggests that this new approach brings concrete advantages.

Beyond LEO, at this point the government must take the lead in developing deep-space capabilities, but we can do so with the hope that the commercial model may ultimately mature to the point where it can play a role analogous to the one it is just beginning to play in low-Earth orbit. That remains to be seen, but the optimists' view of

[7] "National Aeronautics and Space Administration Authorization Act of 2010," Pub. L. No. 111-267 (Oct. 11, 2010), Section 202(a).
[8] Ibid., Section 202(b).

our future in space is that this, too, will prove credible. For now, the 2010 Authorization calls on NASA to develop a heavy-lift vehicle to preserve the nation's core capabilities in space launch, and to provide a kind of final backup, should it be needed, for cargo or crew delivery to the ISS in the event that other commercial or partner-supplied vehicles fail to meet these needs.

NASA is to build as much as practical on existing capabilities and create a heavy-lift vehicle in the 70-100 tons-to-orbit range. This system is to be evolvable to a 130-ton-to-orbit system.[9] However, the Authorization bill also states that: "Human space flight and future exploration beyond low-Earth orbit should be based around a pay-as-you-go approach. Requirements in new launch and crew systems authorized in this Act *should be scaled to the minimum necessary to meet the core national mission capability needed to conduct cislunar missions*. These initial missions, along with the development of new technologies and in-space capabilities can form the foundation for missions to other destinations. These initial missions also should provide operational experience prior to the further human expansion into space."[10] We should not lose sight of this "minimum necessary requirements" criterion, and do our best to ensure that funding to maintain this core national capability does not prevent or overly impede the development of the commercial ecosystem in LEO that may be our best longer-term hope for a robust human future in space. If there is one place where new resources should be targeted to mitigate NASA's budget dilemma, it is here.

[9] Ibid., Section 302(c).
[10] Ibid., Section 301(a)(7). Italics are mine.

**Conclusion**

Forty years after Apollo, the decade following President Kennedy's pledge to land a man on the Moon is still remembered as NASA's heroic age. We cannot help but admire the achievements of that time. But it may be that the power of this memory and admiration can also work against us. It is sometimes said that NASA isn't the agency that it was in 1965. But in FY 2009 dollars, that agency then was spending nearly $20 billion, not $10 billion, per year on human spaceflight.

Twice since Apollo, U.S. Presidents have announced Apollo-like projects. President George H. W. Bush declared his Space Exploration Initiative in 1989 to send astronauts to Mars, but no corresponding budget was forthcoming. President George W. Bush announced his Vision for Space Exploration in 2004, but the budget not only was not sustained, it was not quite there from the beginning. We should learn from the four decades after Apollo as much as from the decade of Apollo. And the lesson of those four subsequent decades seems to be that we cannot hope to be successful by declaring new Apollo-like programs for space exploration.[11]

All the dramatic artists' renditions in our reports or powerpoint slides won't make it so. We are not going to spend $10 billion per year more for human spaceflight. Our Committee argued that $3 billion per year more could enable exploration beyond LEO on a reasonable timescale. Evidently that, too, is not going to happen. If not, then experience should triumph over hope and we should embrace a different model.

That model would be one where we systematically assemble the capacity and infrastructure that will, over time, enable our expansion into the Solar System. We would

[11] See Roger Handberg, "Small Ball or Home Runs: The Changing Ethos of U.S. Human Spaceflight Policy," *The Space Review*, January 17, 2011, available at http://www.thespacereview.com/article/1759/1.

maintain key national capabilities and develop the heavy-lift capacity that will be needed—and develop it in a way that is evolvable to greater demands in the future. But we would also strongly support the robust growth of a space-launch-to-LEO "ecosystem" of cargo and crew capabilities, and recognize this as a model for the future that we want to encourage. Synergistically, NASA would develop technologies that might prove to be game-changers, or at least game-evolvers, such as fuel depots in low-Earth orbit or beyond. We would work toward human operations in cislunar space,[12] then move out. But this time, as we went, we would try to create a human spaceflight ecosystem in the wake of our exploration. Let's see if we can.

[12] "Cislunar" space is defined to be the region of space around Earth and out to and including the region of space around the surface of the Moon.