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

Charting a Course: Expert Perspectives on NASA's Human Exploration Proposals

Wednesday, February 3, 2016
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

On Wednesday, February 3, 2016, the Space Subcommittee will hold a hearing titled *Charting a Course: Expert Perspectives on NASA's Human Exploration Proposals.* The purpose of this hearing is to examine the options for intermediate missions as well as research, technology, and systems needed before NASA can safely and effectively carry out a human mission to Mars, while maintaining a constancy of purpose and steady technical progress through the next Presidential Administration and beyond.

Witnesses

- **Mr. Tom Young**, Former Director, Goddard Space Flight Center, NASA; Former President and Chief Operating Officer, Martin Marietta Corporation
- **Dr. John C. Sommerer**, Chair, Technical Panel, Pathways to Exploration Report, National Academy of Sciences
- **Dr. Paul Spudis**, Senior Scientist, Lunar and Planetary Institute

Background

Following the Space Shuttle *Columbia* accident in February 2003 and the subsequent investigation into its cause, President George W. Bush announced a new "Vision for Space Exploration" on January 14, 2004, to reinvigorate and redirect NASA's human exploration program beyond the International Space Station. The plan focused on the next steps for low-Earth orbit and beyond. It also provided a general vision that the NASA Administrator could use to "implement an integrated, long-term robotic and human exploration program structured with measurable milestones and executed on the basis of available resources, accumulated experience, and technology readiness."[1] The plan included four main goals and objectives: to implement a sustained and affordable human and robotic program to explore the solar system; to extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations; to develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and promote international and commercial participation in exploration to further U.S. scientific, security, and

[1] National Aeronautics and Space Administration-*The Vision for Space Exploration, February 2004.* Retrieved at http://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf

economic interests.[2] The Constellation Program was born out of the Vision for Space Exploration of 2004 and the work for this new program began with NASA's budget request for fiscal year 2005.

After his appointment as Administrator in April 2005, Dr. Mike Griffin ordered a review of NASA's exploration architecture called the "Exploration Systems Architecture Study" (ESAS) to carry out this vision. After the completion of the study, NASA began, with the concurrence of Congress, to restructure the exploration program with an emphasis on acceleration of the development of capabilities to ferry astronauts to the International Space Station.[3] The study recommended the development of a Space Shuttle-derived launch architecture[4] and an exploration vehicle that was capable of carrying cargo and crew to the Space Station as well as crew to the Moon and Mars.[5] Congress codified the majority of the ESAS plan in the National Aeronautics and Space Administration Authorization Act of 2005 (P.L. 109-155), understanding the milestone schedule was based primarily on the ability to "go-as-we-can-afford-to-pay."[6]

In 2009, President Obama ordered a review of the Constellation program and acting NASA Administrator Chris Scolese established the "Review of U.S. Human Spaceflight Plans Committee" (the Commission and also known as the "Augustine Commission") chaired by Norman R. Augustine. The charter for the Commission called for an "independent review of ongoing U.S. human space flight plans and programs, as well as alternatives, to ensure the Nation is pursuing the best trajectory for the future of human space flight—one that is safe, innovative, affordable, and sustainable."[7] The Commission released its final report on October 22, 2009.[8]

The Commission found that "the ultimate goal of human exploration is to chart a path for human expansion into the solar system,"[9] but that "since Constellation's inception, the program has faced a mismatch between funding and program content"[10] and "[d]ifferences between the original Constellation program planning budget and the actual implementation budget, coupled with technical problems that have been encountered on the [programs], have produced the most significant overall impacts to the execution of the Constellation program."[11] The Commission offered five options for the future of the human exploration program, two of which complied with the FY2010 budget profile of the Obama Administration for the Constellation program.[12] However, the Commission noted that neither of these two options would "permit human exploration to continue in any meaningful way."[13]

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[2] *Ibid.*
[3] National Aeronautics and Space Administration Exploration Systems Architecture Study (pg 59). Retrieved at http://www.nasa.gov/pdf/140632main_ESAS_02.pdf
[4] *Ibid.* at pg 717
[5] *Ibid.* at pg 714
[6] Public Law 109-155 NASA Authorization Act of 2005: https://www.gpo.gov/fdsys/pkg/PLAW-109publ155/pdf/PLAW-109publ155.pdf
[7] Charter of the "Review of U.S. Human Spaceflight Plans Committee". retrieved at http://www.nasa.gov/pdf/354415main_Charter%20-%20Signed%20-%20Clean.pdf
[8] Final Report of the "Review of U.S. Human Spaceflight Plans Committee". Retrieved at: http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf
[9] *Ibid.*at pg 9
[10] *Ibid.*at pg 58
[11] *Ibid.*at pg 59
[12] http://www.nasa.gov/pdf/345955main_8_Exploration_%20FY_2010_UPDATED_final.pdf. Note the significant change in the budget projection for the Constellation program from the FY 2010 budget profile on page EXP-2.
[13] Final Report of the "Review of U.S. Human Spaceflight Plans Committee." P. 16. Retrieved at: http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf

In February 2010, President Obama offered a budget for fiscal year 2011 that proposed to cancel the Constellation program.[14] Later that same year, Congress authorized some of the changes to the human exploration program sought by the President[15] as outlined in a speech on April 15, 2010. In this speech at the Kennedy Space Center he revealed his strategy for the future of human exploration which canceled a return mission to the Moon, saying, "I understand that some believe that we should attempt a return to the surface of the Moon first, as previously planned. But I just have to say pretty bluntly here: We've been there before… Early in the next decade, a set of crewed flights will test and prove the systems required for exploration beyond low Earth orbit. And by 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the Moon into deep space. So we'll start -- we'll start by sending astronauts to an asteroid for the first time in history. By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth. And a landing on Mars will follow."[16]

Stepping Stones to Mars

The NASA Authorization Act of 2015 (H.R. 810), which passed the House of Representatives unanimously last February, included a requirement that NASA produce a "human exploration roadmap."[17] Among other things, the roadmap would include "specific capabilities and technologies necessary to extend human presence to the surface of Mars and the sets and sequences of missions required to demonstrate such capabilities and technologies."[18] As the Senate has not passed a NASA Authorization act since 2010, the Administration has received no guidance from Congress on its programs since 2013, when the NASA Authorization Act of 2010 expired.

As NASA prepares to take the next steps in human exploration of the solar system, there remain many unanswered questions about the correct path to Mars and beyond. The Apollo Program was not a straight shot to the Moon; it included several precursor missions to test new capabilities and gain experience on the way to the Moon, including Projects Mercury and Gemini. In much the same way, NASA will need to acquire new capabilities to travel to Mars and beyond. The two most commonly discussed possibilities for precursor missions to Mars involve crewed missions to the Moon or an asteroid.

In October 2015, NASA released a document titled *NASA's Journey to Mars, Pioneering Next Steps in Space Exploration*.[19] In the report, the agency provided general descriptions about the future of human exploration to Mars including the Asteroid Retrieval Mission (ARM) as a necessary "near term opportunity to demonstrate several capabilities important for longer-duration, deep-space missions…"[20] This report did not mention any potential missions for the lunar surface.

The importance of keeping human exploration program on track across Presidential transitions has been an ongoing challenge. Multiple NASA advisory panels and commissions that study the human

[14] President's Budget Request for the National Aeronautics and Space Administration, Fiscal Year 2011. Retrieved at http://www.nasa.gov/news/budget/2011.html
[15] Public Law 111-267: National Aeronautics and Space Administration Authorization Act of 2010: https://www.congress.gov/111/plaws/publ267/PLAW-111publ267.pdf
[16] Speech by President Obama at Kennedy Space Center on April 15, 2010 http://www.nasa.gov/news/media/trans/obama_ksc_trans.html
[17] H.R. 810, the National Aeronautics and Space Administration Authorization Act of 2015, Section 202: https://www.congress.gov/114/bills/hr810/BILLS-114hr810rfs.pdf
[18] *Ibid.*
[19] "NASA's Journey to Mars, Pioneering Next Steps in Space Exploration." Released in October of 2015. Retrieved at http://www.nasa.gov/sites/default/files/atoms/files/journey-to-mars-next-steps-20151008_508.pdf
[20] *Ibid.* at pg. 21.

exploration program have concluded that the importance of keeping the program of record on track is paramount to ensuring budget and schedule stability.

In preparation for the future of NASA's human exploration program beyond the current Administration, the NASA Advisory Council (NAC) recently released a public recommendation to the Administrator that NASA should further develop its plan for future human exploration. The NAC concluded that without further definition to these plans, it would impair the ability of the next Administration to propose a budget that "adequately support[s] NASA's Human Exploration Program."[21]

NASA Administrator Charles Bolden recently reiterated his concerns about maintaining the current track of exploration programs. In remarks at the Center for American Progress, the Administrator commented that, ""If we change our minds at any time in the next three or four years, which always is a risk when you go through a government transition, my belief is that we're doomed." He also remarked that constant restarts of the exploration programs have a negative effect on the overall effort, "I think we've been through enough 'start overs' to know that people grow weary. People like to see something where you're persistent."[22]

Additionally, the Aerospace Safety Advisory Panel (ASAP) reissued a call for constancy of purpose in its annual report released on January 13, 2016. The panel stated, "As in prior reports, the ASAP urges constancy of purpose. Failing to stay the course with current programs of record will make it an even longer, costlier, and potentially less safe trip to Mars."[23]

Lunar Mission

The *Vision for Space Exploration* called for a return to the Moon by 2020 as a stepping stone to other locations, and NASA has continued various lunar science projects such as the Lunar Reconnaissance Orbiter (LRO) and the Gravity Recovery and Interior Laboratory (GRAIL). The Constellation program was ideally suited for a human landing on the Moon, to include development of a lunar lander called *Altair* as one of the systems to develop. Since the cancellation of the Constellation program, there is no longer a lunar lander under development.

There are several compelling reasons for using the Moon as a training ground and test bed to prepare for more complex missions. Landing on the Moon would develop technical capabilities for landing on and launching from a large celestial body, something NASA has not done for more than four decades.[24] According to a report published by the Planetary Society, "getting humans to Mars by the 2030s will require new hardware and space-based operations that must be demonstrated closer to Earth."[25] The report goes on to explain the necessity of returning humans to the surface of

[21] NASA Advisory Council Recommendation to the Administrator 2015 04-04-01 (Council-01). December 3, 2015. http://www.nasa.gov/sites/default/files/atoms/files/final_recommendations_dec2015_tagged.pdf
[22] "Bolden: NASA "Doomed" if Next President Dumps Journey to Mars" October 29, 2015. http://spacenews.com/bolden-nasa-doomed-if-next-president-dumps-journey-to-mars/#sthash.y4VwiLUN.dpuf
[23] Aerospace Safety Advisory Panel Annual Report for 2015. Retrieved at http://oiir.hq.nasa.gov/asap/documents/2015_ASAP_Annual_Report.pdf
[24] The last time humans landed on the moon was Apollo 17 on December 7, 1972.
[25] Humans Orbiting Mars: A Critical Step Toward the Red Planet. September 28, 2015. http://planetary.s3.amazonaws.com/assets/pdfs/advocacy/2015/Planetary-Society--Humans-Orbiting-Mars-Workshop-Report-%5BFinal.v2%5D.pdf

the Moon "within the context of an end-to-end test of the Mars lander system and a simulation of Mars surface operations."[26]

Establishing a semi-permanent or permanent presence on the Moon such as the lunar outpost referenced in the NASA Authorization Acts of 2005 and 2008,[27] would give astronauts an opportunity to work and live in an environment radically different from Earth, in much the same way explorers on Mars would need to work and live. Ultimately, operating on another planet will require training and preparation, the Moon seems like a logical place to do this training.

On the international front, there appears to be continued enthusiasm for a mission to the Moon."[28] Recently, Jan Woerner, the Director General of the European Space Agency, proposed the development of an international Moon "village" as a next step for international human exploration efforts.[29] Additionally, Roscosmos Energia announced plans for a human mission to the lunar surface in 2029.[30]

Although there is increased energy from international partners, NASA continues to rebuff any notion of landing humans on the surface of the moon. Both President Obama and Administrator Bolden have said that landing humans on the surface of the moon is not a priority.[31]

Asteroid Mission

The National Space Policy issued by President Obama in April 2010, and released formally later that year, envisioned sending humans to an asteroid by the year 2025 beyond lunar orbit into "deep space."[32] The National Research Council issued a report in December 2014 which stated that "[t]he committee has seen little evidence that a current stated goal for NASA's human spaceflight program—namely, to visit an asteroid by 2025—has been widely accepted as a compelling destination by NASA's own workforce, by the nation as a whole, or by the international community."[33]

The Administration proposed a revised asteroid mission with the FY2014 budget request. The mission concept proposed by the Administration features a robotic capture and redirection of a small near Earth asteroid (NEA) to a deep retrograde lunar orbit for astronauts to visit rather than sending Astronauts to an asteroid in deep space.

After significant study efforts and criticism from scientists, engineers, and policy-makers, the Administration proposed another revision to the mission in March 2015. This time, the proposal included a robotic sample capture and retrieval mission. Under the revised proposal, a robotic spacecraft would go to a large asteroid, pull a boulder off an asteroid, and return it to a distant

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[26] *Ibid.*
[27] 51 USC 70505
[28] NASA's Strategic Direction and the Need for a National Consensus http://www.nap.edu/catalog.php?record_id=18248
[29] "Moon village is best way to replace International Space Station - ESA head" Reuters News Service, January 15, 2016. http://www.reuters.com/article/europe-space-moon-idUSL8N14Z1WB
[30] "Russia's Big Plan To Finally Put Cosmonauts on the Moon" January 6, 2016. http://www.popularmechanics.com/space/moon-mars/a18849/russia-plan-cosmonauts-moon/
[31] "As NASA Shrugs, FAA Looks at Leadership Role in Global Moon Village," November 3, 2015. http://spacenews.com/as-nasa-shrugs-faa-looks-at-leadership-role-in-global-moon-village/
[32] National Space Policy. Released on June 28, 2010. Pg. 11. Retrieved at https://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf
[33] National Research Council Report: Pathways to Exploration. Retrieved at http://www.nap.edu/catalog/18801/pathways-to-exploration-rationales-and-approaches-for-a-us-program

retrograde lunar orbit for exploration by astronauts.[34] As with previous proposals, there is no budget estimate for the mission.

At its meeting in April 2015, the NASA Advisory Council issued a recommendation to the Administrator that NASA's stated use of solar electric propulsion in the ARM mission would "likely be an important part of an architecture to send humans to Mars." And that "maneuvering a large test mass is not necessary to provide a valid in-space test of a new SEP Stage." The NAC concluded its recommendation to the Administrator by saying, "instead of relocating a boulder from an asteroid, [the NAC] suggests that a more important and exciting first use of this new SEP stage would be a round trip mission to Mars."[35]

NASA recently published for comment a draft report on the architecture of the mission referred to as the FAST (Formulation Assessment and Support Team) report. The purpose of the report was to "to provide timely inputs for mission requirement formulation in support of the Asteroid Redirect Robotic Mission (ARRM) Requirements Closure Technical Interchange Meeting (TIM) in mid-December of 2015, to assist in developing an initial list of potential mission investigations, and to provide input on potential hosted payloads and partnerships."[36]

The FAST report provided background on the purpose of ARRM, responded to common questions about the mission, provided analysis of potential science investigations, and evaluated the necessity of the mission for future human exploration efforts. The report was released on the Monday before the Thanksgiving Day holiday and public comments were required within 10 days before the comment period closed.

Issues

As Congress begins planning for the first budget year under a different President, there are several issues under consideration and outstanding questions, among them:

- How can Congress provide a better constancy of purpose for NASA's human exploration program so that it does not endure another costly cancelation as the Constellation Program and other, previous NASA programs?
- What are the most important skills, technologies, and processes necessary for future Mars missions and how should the development of these elements be phased?
- What advantages and disadvantages are there of missions to the Moon or asteroids or other destinations?
- How do NASA's plans for future human exploration missions affect the United States' relationships with international partners?
- How should NASA incorporate international participation as well as commercial and philanthropically-funded programs in its human spaceflight plans and programs beyond low Earth orbit?

Appendix- Reports on Space Exploration

[34] NASA Announces Next Steps on Journey to Mars: Progress on Asteroid Initiative. NASA Press Release, March 25, 2015. http://www.nasa.gov/press/2015/march/nasa-announces-next-steps-on-journey-to-mars-progress-on-asteroid-initiative

[35] NASA Advisory Council Recommendations to the Administrator, April 9-10, 2015. Retrieved at http://www.nasa.gov/sites/default/files/atoms/files/april9-10_finalrecom-tagged.pdf

[36] Draft Formulation Assessment and Support Team Report. Published November 23, 2015. https://www.nasa.gov/sites/default/files/atoms/files/fast-final-report-draft-for-public-comment.pdf

1986 - The National Commission on Space (Paine Commission Report)
http://www.nasa.gov/pdf/383341main_60%20-%2020090814.5.The%20Report%20of%20the%20National%20Commission%20on%20Space.pdf

1987 - NASA Leadership and America's Future in Space: A Report to the Administrator (Ride Report)
http://history.nasa.gov/riderep/main.PDF

1990 – Advisory Committee on the Future of the U.S. Space Program (Augustine Commission Report)
http://www.hq.nasa.gov/office/pao/History/augustine/racfup1.htm

1991 – The Synthesis Group (The Stafford Report)
http://history.nasa.gov/staffordrep/main_toc.PDF

1991 - Office of Technology Assessment: Exploring the Moon and Mars
http://history.nasa.gov/32992.pdf

1993 – The National Space Council Report on the U.S. Space Program
http://history.nasa.gov/33082.pt1.pdf

2004 – President's Commission on Implementation of United States Space Exploration Policy (Aldridge Commission Report)
http://history.nasa.gov/aldridge_commission_report_june2004.pdf

2009 – Review of U.S. Human Space Flight Plans Committee (Augustine Commission Report)
http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf