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

HEARING CHARTER

Keeping Our Sights on Mars: A Review of NASA's Deep Space Exploration Programs and Lunar Proposal

Wednesday, May 8, 2019
2:00 p.m.
2318 Rayburn House Office Building

PURPOSE

The purpose of the hearing is to review the National Aeronautics and Space Administration's (NASA's) deep space human exploration programs, including proposed lunar activities and the budgetary resource requirements for those activities, in the context of the long-term goal of sending humans to the surface of Mars.

WITNESSES

- **Mr. William H. Gerstenmaier,** Associate Administrator, Human Exploration and Operations, National Aeronautics and Space Administration
- **Mr. Mark Sirangelo,** Special Assistant to the Administrator, National Aeronautics and Space Administration
- **Dr. Jonathan Lunine,** Director, Cornell Center for Astrophysics and Planetary Science, Co-Chair of the Former Committee on Human Spaceflight, National Academies of Sciences, Engineering, and Medicine
- **Dr. Patricia Sanders,** Chair, Aerospace Safety Advisory Panel
- **Mr. J. Walter Faulconer,** President, Faulconer Consulting Group

OVERARCHING QUESTIONS

- *What are the goals, objectives, plans, and budgetary requirements for the Administration's proposal to send humans to the lunar surface in 2024 and to sustain a long-term presence there?*
- *To what extent do the Administration's proposed lunar plans contribute directly to buying-down the technical and overall risks involved in a human mission to Mars?*
- *What are the safety, technical, and programmatic risks associated with the lunar proposal?*

BACKGROUND

The NASA deep space human exploration program and activities include the heavy-lift Space Launch System (SLS), the Orion crew vehicle, Exploration Ground Systems (EGS), and Exploration Research and Development. The International Space Station (ISS), which organizationally exists in the low Earth orbit (LEO) and Spaceflight Operations program account, supports future deep space exploration activities through human health research, technology demonstrations, human spaceflight operations, and knowledge gained from astronauts' living and working in space.

In March 2017, the NASA Transition Authorization Act of 2017 was enacted into law.[1] The Act reiterates previous NASA Authorizations regarding a stepping-stone approach to human exploration and adds language on achieving the objective to human exploration of Mars, as funding allows.

In December 2017, President Trump issued Space Policy Directive-1, which amended existing National Space Policy Directive-4 of June 2010 to include the "*return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations.*"[2] Subsequently, NASA organized its human exploration programs to focus on the Moon.

Exploration Campaign as Proposed in the Fiscal Year (FY) 2020 NASA Budget Request

The NASA exploration budget request for FY 2020 is combined under the Exploration Campaign Total budget line, as detailed in the table below[3] and proposes a total of $10.7 billion for FY 2020, a 2 percent cut from the FY 2019 appropriation. The FY 2020 budget request prioritizes human exploration and lunar activities with increased funding for these objectives. Under the FY 2020 proposal, NASA would target a 2028 human landing on the Moon. However, two weeks after the release of the FY 2020 budget request for NASA, the White House directed NASA to work toward a 2024 lunar landing. NASA Administrator, James Bridenstine, testified before the Committee on April 2, 2019[4] and committed to providing further details on the accelerated lunar landing proposal and a budget amendment to the Committee by about April 15, 2019. The Committee has not yet received a revised lunar plan, a budget amendment that includes annual resource requirements, or a proposed acquisition approach. Administrator Bridenstine also testified before the Senate Committee on Appropriations, Subcommittee on Commerce, Justice, Science, and Related Agencies on May 1, 2019 where he did not provide details on a lunar plan or budget amendment.

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[1] P.L 115-10.
[2] Presidential Memorandum on Reinvigorating America's Human Space Exploration Program, December 11, 2017. https://www.whitehouse.gov/presidential-actions/presidential-memorandum-reinvigorating-americas-human-space-exploration-program/
[3] Table from page EXC-1, NASA FY2020 Budget Request Congressional Justification
[4] "A Review of the NASA FY2020 Budget Request," April 2, 2019. https://science.house.gov/hearings/a-review-of-the-nasa-fy2020-budget-request

Budget Authority (in $ millions)	Actual FY 2018	IOP FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Exploration Campaign TOTAL	**$10,449.0**	**$10,927.6**	**$10,712.3**	**$11,147.1**	**$11,542.3**	**$12,637.9**	**$13,068.0**
Deep Space Exploration Systems	$4,790.0	$5,050.8	$5,021.7	$5,295.5	$5,481.4	$6,639.0	$7,042.3
Exploration Technology	$760.0	$926.9	$1,014.3	$976.1	$995.4	$964.4	$943.1
LEO & Spaceflight Operations	$4,749.2	$4,639.1	$4,285.7	$4,369.5	$4,369.5	$4,235.5	$4,182.3
Exploration Campaign COF	$119.8	$42.8	$71.6	$0.0	$0.0	$0.0	$0.0
Elements of Science+	$30.0	$268.0	$319.0	$506.0	$696.0	$799.0	$900.3
Change from FY 2019 PBR			**$-215.3**				
Percentage change from FY 2019			**-2.0%**				

+Elements of Science: Lunar Discovery & Exploration Program and Mars Sample Return

National Academies' Pathways to Exploration Report

In June 2014, the National Academies released *Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration*, referred to hereafter as *Pathways.*[5] The study was carried out pursuant to the NASA Authorization Act of 2010.[6] The report entailed an "*explicit examination of rationales, along with the identification of enduring questions,* [which] *set the task apart from numerous similar studies performed over the preceding several decades, as did the requirement that the committee bring broad public and stakeholder input into its considerations.*"

The National Academies' Committee on Human Spaceflight, which authored the *Pathways* report, concluded that a "*sustainable program of human deep-space exploration requires an ultimate "horizon" goal that provides a long-term focus that is less likely to be disrupted by major technological failures and accidents along the way or by the vagaries of the political process and the economic scene.*" The committee found that "*the horizon goal for human space exploration is Mars*," having observed that "*all long-range space programs, by all potential partners, for human space exploration converge on*" that goal.

With Mars as the ultimate horizon goal, the study committee concluded that "*NASA can sustain a human exploration program that pursues the horizon goal of a surface landing on Mars with meaningful milestones and simultaneously reasserts U.S. leadership in space while allowing ample opportunity for substantial international collaboration—but only if the program has elements that are built in a logical sequence, and when it can fund a frequency of flights sufficiently high to ensure the maintenance of proficiency among ground personnel, mission controllers, and flight crews.*"

The committee further concluded that the best way to achieve a sustainable human exploration program that is responsive to their findings on rationales and enduring questions is to "*develop a program through the rigorous applications of a set of pathway principles.*" The committee

[5] National Research Council. 2014. *Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration.* Washington, DC: The National Academies Press. https://www.nap.edu/catalog/18801/pathways-to-exploration-rationales-and-approaches-for-a-us-program

[6] Section 201, P.L 111-267.

defined a "pathway" as "*a specific sequence of intermediate accomplishments and destinations normally of increasing difficulty and complexity, leading to an ultimate (horizon) goal, with technology feed-forward from one mission to subsequent missions*". The highest-recommended pathway principles included: committing to an exploration pathway beyond LEO; engaging international partners early in the design and development of the pathway; defining steps that foster sustainability and maintain progress on the horizon goal; creating a risk-mitigation plan, including decision rules for off-ramps as necessary; and establishing pathway characteristics that maximize the overall scientific, cultural, economic, political, and inspirational benefits without sacrificing progress toward the long-term goal.

The study committee examined three pathways, each with a Mars horizon goal, in terms of the trade-offs among schedule, development risk, affordability, and ISS lifetime (considering decommissioning dates of either 2020 or 2028):

- **Asteroid Redirect Mission (ARM)-to-Mars pathway** would start with astronaut interactions with a near-Earth asteroid in its native orbit, then on to the Martian moons, and finally to the Martian surface.[7]
- **Moon-to-Mars pathway** would use the Moon as a testing and development platform to mature Mars-relevant technology and do scientific exploration of the lunar surface.
- **Enhanced Exploration pathway** would begin with activities in cislunar space, then proceed to an asteroid, to lunar surface missions and an outpost, then to the moons of Mars, and then to the surface of Mars.

In considering budgets, the committee concluded that "*A continuation of flat budgets for human spaceflight is insufficient for NASA to execute any pathway to Mars and limits human spaceflight to LEO until after the end of the ISS*," and further that, even with annual increases to the NASA human spaceflight budget to keep pace with inflation, "*technical and operational risks do not permit a viable pathway to Mars.*" The committee determined that increasing the NASA budget such that the funding for human spaceflight could increase annually by 5% (twice inflation) "*would enable pathways with potentially viable mission rates, greatly reducing technical, cost, and schedule risk.*"

The report identified the following technological capabilities as high priorities for a human mission to Mars, and specifically called out the first three as the top priorities:

- **Mars Entry, Descent, and Landing (EDL)**
- **Radiation Safety**
- **In-Space Propulsion and Power**
- Heavy Lift Launch Vehicles
- Planetary Ascent Propulsion
- Environmental Control and Life Support Systems (ECLSS)
- Habitats
- Extravehicular Activity (EVA) Suits
- Crew Health

[7] NASA had been following a program along the ARM pathway, but the program was closed out in June 2017.

- In-Situ Resource Utilization (ISRU) from the Martian Atmosphere

The report includes an assessment of the technical, regulatory, and cost/schedule challenges and capability gaps associated with each of these high-priority technologies.

Evaluation of a Human Mission to Mars by 2033

Pursuant to the NASA Transition Authorization Act of 2017,[8] NASA requested that the Institute for Defense Analyses Science and Technology Policy Institute (STPI) conduct a study on the technical and budgetary feasibility of launching a human spaceflight mission to Mars by 2033. The report, "Evaluation of a Human Mission to Mars by 2033,"[9] hereafter "the Mars 2033 report," was transmitted to Congress in March 2019.[10] The report was based on NASA's *National Space Exploration Campaign Report*,[11] discussions with NASA personnel, and publicly-available documents, including the FY 2019 budget request and presentations to the NASA Advisory Council (including the notional plan to return humans to the Moon in 2028, although the new direction from Vice President Pence in March 2019 moves that goal to 2024).

The main architectural elements of a human orbital mission to Mars are the heavy-lift SLS, the Orion crew vehicle, the Gateway, and the notional Deep Space Transport (DST) vehicle. The Mars 2033 report assigned the following risk levels for these components to a human spaceflight mission orbiting Mars:

- **SLS/Orion: Low –** *"due to long development programs and ongoing testing."*[12]
- **Gateway: Medium** – as some technologies have not yet been adequately demonstrated. The first module will be the Power and Propulsion Element, currently planned for launch in 2022. However, because of schedule constraints, ground testing for its major thruster system is not planned, which contributes to the medium technological risk. Other risks include the autonomous environmental monitoring for its uninhabited period of time as well as deep space, human-rated batteries.
- **DST: High –** because *"the DST requires several medium and high-risk technologies,"* most notably the ECLSS. Other areas of medium to high risk include cryogenic propellants, system integration, space suits, and propulsion. Several technologies are at low technological readiness levels and would require several years of development time to be ready for full implementation. Some elements would not be significantly matured

[8] Section 435, P.L 115-10.
[9] IDA Science and Technology Policy Institute. 2019. "Evaluation of a Human Mission to Mars by 2033." https://www.ida.org/idamedia/Corporate/Files/Publications/STPIPubs/2019/D-10510.pdf
[10] STPI submitted a prior version of the report to NASA in December 2017. After Space Policy Directive-1 was released in December 2017, STPI was asked to update the report, and to use the NASA Exploration Campaign Report that was transmitted to Congress in September 2018 as the basis for NASA's exploration plans.
[11] NASA. 2018. *National Space Exploration Campaign Report*. Submitted pursuant to Section 432(b) of the NASA Transition Authorization Act of 2017 (P.L. 115-10). https://www.nasa.gov/sites/default/files/atoms/files/nationalspaceexplorationcampaign.pdf
[12] However, since the completion of the report, an April 26, 2019 article in *Ars Technica* noted that NASA announced that it anticipates further delays in SLS launch dates and requested in its FY 2020 budget request to defer development of upgraded SLS variants which would enable heavier lift capability.

by the Gateway or lunar surface activities and thus would require additional research and development before use at Mars.

The Mars 2033 report also assessed the risks to human health in the orbital mission to Mars and found that *"a review of internal NASA planning documents and academic literature reveals that the understanding of human health risks associated with a 1,100-day human orbital mission to Mars is limited."* STPI additionally found that NASA's current approach to addressing human health risk factors for a mission to Mars presented a high risk because the plan lacked *"sufficient detail in both evidence and strategy to justify the predicted timeline to develop risk mitigation strategies, or even estimate a realistic cost to retire the risks."*

Given the notional plan to land humans on the Moon in 2028 presented to the advisory committees in November and December,[13] STPI assessed the feasibility of potential timelines for launch of a human spaceflight mission to orbit Mars:

- 2033: "*infeasible under all budget scenarios and technology development and testing schedules"*
- 2035: *"may be possible under budgets that match 1.9 percent real growth, but carries high risks of schedule delays due to complex technology development, testing, and fabrication schedules for the DST; may require reducing the scope of lunar missions; and reduces NASA's ability to mitigate risks to human health"*
- 2037: *"the earliest the DST could feasibly depart for Mars assuming a small budget increase or smoothing budgets over two time periods in the 2030s"*
- 2039: "*a more realistic timeframe if there are delays or budget shortfalls affecting the acquisition or testing of the DST"*

In comparison, the *Pathways* report states "*The Moon-to-Mars pathway could yield a landing between 2043 and 2050*."

Aerospace Safety Advisory Panel 2018 Annual Report

The Aerospace Safety Advisory Panel (ASAP) was chartered by Congress in 1968 to advise and make recommendations to the NASA Administrator and Congress on safety aspects of NASA activities. The ASAP prepares an annual report to convey issues and concerns it has identified at its meetings held during the year. While there are several areas related to Exploration discussed in the 2018 ASAP Annual Report,[14] selected statements from the report are highlighted below:

- *"In order to mitigate the considerable risk of human exploration in the far reaches of space, it is imperative that NASA maintains a persistent presence in LEO where it can test the technologies necessary for interplanetary voyages with its requisite life support and to continue its understanding of the impacts of space travel on human physiology.*"

[13] e.g., Presentation by William H. Gerstenmaier to the NASA Advisory Council, "NASA Exploration Update," December 10, 2018.
https://www.nasa.gov/sites/default/files/atoms/files/nasa_exploration_update_dec2018_tagged.pdf
[14] Aerospace Safety Advisory Panel Annual Report for 2018.
https://oiir.hq.nasa.gov/asap/documents/2018_ASAP_Report-TAGGED.pdf

- The Exploration Systems Development Program "*should clearly identify which systems or components must absolutely be present on EM-1* [Exploration Mission-1] *for them to be considered qualified for operation on EM-2. Crew risk mitigation on EM-2 depends on the flight demonstration of some elements of various systems. It is our position that those components, parts, or systems need to be directly identified by the Program and those essential elements be incorporated before the EM-1 flight is launched."*
- Regarding preparations for the first integrated tests of the SLS and Orion vehicles, EM-1 and EM-2, the ASAP stated, *"The Environmental Control and Life Support System (ECLSS) is a principal EM-2 element that needs completion and qualification. The ASAP continues to be concerned about whether this system will be fully tested, qualified, and ready to support the crew launch for EM-2. Although NASA has informed the Panel about ECLSS testing, which is currently scheduled in 2021, we have not seen the plan for validation of the entire integrated system. While some components of the system are being operated on the ISS for microgravity experience, this component work does not substitute for integrated system operational validation.*"
- *"As NASA enters into new arrangements with commercial and international partners, we strongly suggest that an examination of the CCP* [Commercial Crew Program] *business model—as well as the lessons learned from the ISS—be taken into consideration. There will be tremendous value in understanding the complexities that are experienced in managing and mitigating risks that may be shared by multiple national and industrial partners."*