STEP BY STEP: THE ARTEMIS PROGRAM AND NASA'S PATH TO HUMAN EXPLORATION OF THE MOON, MARS, AND BEYOND

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

OF THE

HOUSE OF REPRESENTATIVES

ONE HUNDRED NINETEENTH CONGRESS

FIRST SESSION

FEBRUARY 26, 2025

Serial No. 119–3

Printed for the use of the Committee on Science, Space, and Technology

Available via the World Wide Web: http://science.house.gov

U.S. GOVERNMENT PUBLISHING OFFICE

58–904PDF WASHINGTON : 2025

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HON. BRIAN BABIN, Texas, *Chairman*

RANDY WEBER, Texas
JIM BAIRD, Indiana
DANIEL WEBSTER, Florida
JAY OBERNOLTE, California
CHUCK FLEISCHMANN, Tennessee
DARRELL ISSA, California
CLAUDIA TENNEY, New York
SCOTT FRANKLIN, Florida
MAX MILLER, Ohio
RICH McCORMICK, Georgia
MIKE COLLINS, Georgia
VINCE FONG, California
DAVID ROUZER, North Carolina
KEITH SELF, Texas
PAT HARRIGAN, North Carolina
SHERI BIGGS, South Carolina
JEFF HURD, Colorado
MIKE HARIDOPOLOS, Florida
MIKE KENNEDY, Utah
NICK BEGICH, Alaska
VACANT

ZOE LOFGREN, California, *Ranking Member*
SUZANNE BONAMICI, Oregon
HALEY STEVENS, Michigan
DEBORAH ROSS, North Carolina
ANDREA SALINAS, Oregon
VALERIE FOUSHEE, North Carolina
EMILIA SYKES, Ohio
MAXWELL FROST, Florida
GABE AMO, Rhode Island
SUHAS SUBRAMANYAM, Virginia
LUZ RIVAS, California
SYLVESTER TURNER, Texas
SARAH McBRIDE, Delaware
LAURA GILLEN, New York
GEORGE WHITESIDES, California,
Vice Ranking Member
LAURA FRIEDMAN, California
APRIL McCLAIN DELANEY, Maryland
JOSH RILEY, New York

SUBCOMMITTEE ON SPACE AND AERONAUTICS

HON. MIKE HARIDOPOLOS, Florida, *Chairman*

DANIEL WEBSTER, Florida
RICH McCORMICK, Georgia
MIKE COLLINS, Georgia
VINCE FONG, California
KEITH SELF, Texas
MIKE KENNEDY, Utah

VALERIE FOUSHEE, North Carolina,
Ranking Member
LAURA GILLEN, New York
GEORGE WHITESIDES, California
HALEY STEVENS, Michigan
ANDREA SALINAS, Oregon

C O N T E N T S

February 26, 2025

STEP BY STEP: THE ARTEMIS PROGRAM AND NASA'S PATH TO HUMAN EXPLORATION OF THE MOON, MARS, AND BEYOND

WEDNESDAY, FEBRUARY 26, 2025

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

The Subcommittee met, pursuant to notice, at 10:06 a.m., in room 2318 of the Rayburn House Office Building, Hon. Mike Haridopolos [Chairman of the Subcommittee] presiding.

COMMITTEE ON
SCIENCE, SPACE
AND TECHNOLOGY
CHAIRMAN BRIAN BABIN

SUBCOMMITTEE ON SPACE & AERONAUTICS

HEARING CHARTER

Step by Step: The Artemis Program and NASA's Path to Human Exploration of the Moon, Mars, and Beyond

Wednesday, February 26, 2025
10:00 A.M.
2318 Rayburn House Office Building

Purpose

The purpose of this hearing is to review outside perspectives of National Aeronautics and Space Administration (NASA) progress on the Artemis program and hear from witnesses about the importance of maintaining the continuity of purpose for NASA's human exploration program. This hearing will assess how the strategy and goals behind NASA's human exploration program have evolved over time from the Vision for Space Exploration to the current Moon to Mars Architecture. The Committee will also consider whether NASA can leverage developments in United States space capabilities to achieve Artemis objectives in a faster and more cost-effective manner. Finally, the hearing will address how today's efforts are directly tied to NASA's future exploration goals, including a crewed mission to Mars.

Witnesses

- **Dr. Scott Pace,** Director of Space Policy Institute, George Washington University
- **Mr. Dan Dumbacher,** Adjunct Professor, Purdue University

Overarching Questions

- What is the status of various elements of Artemis?
- How can Artemis architecture evolve to reduce costs and avoid additional delays?
- How does Artemis help ensure U.S. competitiveness in science and technology?
- What are the Chinese Communist Party's plans for sending astronauts to the Moon?

Background

Human space exploration has been a key NASA tenet since the agency's inception. One of NASA's greatest achievements was conducting a series of lunar landings between 1969 and 1972. NASA was able to achieve its goal of putting Americans on the Moon due, in large part, to clear and consistent direction from the federal government matched with substantial funding. While NASA funding is unlikely to reach Apollo-era levels in the near term, Congress can and should provide clear and consistent direction on the future of human space exploration.

In the decades since the Apollo program, United States human space activity was limited to low Earth orbit. NASA continued to carry out impressive feats, including the Skylab, International Space Station, and Space Shuttle programs. But NASA has not attempted to send astronauts into "deep space" since Apollo 17.

Today's Artemis program is a product of years of debate over the appropriate focus of human space exploration efforts. Throughout such considerations, the importance of maintaining continuity of purpose and goals for human space exploration has been highlighted. For example, the 2014 National Academies Pathways to Exploration report stated that "frequent changes in the goals for U.S. human space exploration (in the context of the decades that will be required to accomplish them) dissipate resources and impede progress."[1] Additionally, the 2021 Aerospace Safety Advisory Panel annual report "stressed the importance of constancy of purpose and its role in the ability of the Agency to manage risk intelligently and proactively."[2]

Through the Artemis Program, NASA seeks to return humans to the lunar surface by leveraging commercial and international partnerships. In addition to promoting national interests, such as technological advancement and economic competitiveness, returning to the Moon will allow NASA to establish best practices and advance scientific research and develop technologies needed to enable future crewed missions to Mars and other deep space destinations.

Evolution of the Artemis Program

The Artemis program and its systems reflect over several decades of study and policymaking related to U.S. human space exploration.

In 2004, President George W. Bush and NASA Administrator Sean O'Keefe released the Vision for Space Exploration, which sought 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."[3] The plan also provided a generalized vision that the 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." The same year, Congress passed the NASA Authorization Act of 2005 which directed NASA to "establish a program to develop a sustained human presence on the Moon […] to promote exploration, science, commerce, and United States preeminence in space, and as a stepping-stone to future exploration of Mars and other

[1] National Academies of Science, Engineering, and Medicine, *Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration,* 2014. Retrieved at https://nap.nationalacademies.org/catalog/18801/pathways-to-exploration-rationales-and-approaches-for-a-us-program
[2] NASA Aerospace Safety Advisory Panel, *2021 Annual Report,* January 2022. Retrieved at https://www.nasa.gov/asap-reports/
[3] National Aeronautics and Space Administration, *The Vision for Space Exploration,* February 2004. Retrieved at http://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf

destinations."[4] Under the Constellation program, NASA began developing exploration hardware to accomplish these goals, including the Ares launch vehicles, an Earth Departure Stage secondary booster, an Orion spacecraft, and an Altair lunar lander.

Despite clear and consistent Congressional support for Constellation during the Bush Administration, on May 7, 2009, President Obama released his presidential budget request (PBR) for Fiscal Year 2010. This budget request cut funding to the exploration account, which included Constellation, by roughly $1 billion per year in the outyears (starting in Fiscal Year 2011).

The same day that the Administration announced it was cutting the budget for Constellation, Dr. Holdren, the President's Science Advisor and Director of the White House Office of Science and Technology Policy, sent a letter to NASA directing the initiation of a "review of ongoing U.S. human spaceflight plans and programs," to see if the program was "sustainable."[5] The final report, titled the "Review of U.S. Human Spaceflight Plans Committee," was chaired by Norman Augustine (commonly referred to as the "Augustine Report."). The Commission released its final report on October 22, 2009.[6]

The primary conclusion of the report was that the current program was "unexecutable."[7] After the Obama Administration reduced funding for the Constellation program, it was not surprising that the Augustine Commission found that the program was underfunded.[8] Despite this, one of the panel members, retired Air Force General Lester Lyles, found that "The current program of record, in my opinion, seems to be the right one."[9] However, based on the Obama Administration's budget request, the report found that "[h]uman exploration beyond low Earth orbit is not viable under the [fiscal] 2010 budget guideline."[10]

Despite this, the Obama Administration canceled Constellation in 2010 and instead opted to pursue a crewed mission to an asteroid as a predecessor to an eventual Mars mission. During the same period, Congress passed the NASA Authorization Act of 2010, reaffirming the commitment to human space exploration, preserving some elements of the Constellation program, including the Orion spacecraft, and initiating development of the Space Launch System (SLS) rocket.[11]

In 2017, the Trump Administration directed NASA to "lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other

---

[4] National Aeronautics and Space Administration Authorization Act of 2005 (P.L. 109-155)
[5] Office of Science and Technology and Policy, *Letter -- OSTP Director John Holdren to NASA Acting Administrator Chris Scolese,* May 2009. Retrieved at: https://obamawhitehouse.archives.gov/the-press-office/2015/11/16/letter-ostp-director-john-holdren-nasa-acting-administrator-chris
[6] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, October 2009. Retrieved at https://www.nasa.gov/wp-content/uploads/2015/01/617036main_396093main_hsf_cmte_finalreport.pdf?emrc=e76114
[7] See Supra 6
[8] Foust, Jeff, "Lyles on Constellation, commercialization, and organization," Space Politics, October 20, 2009. Retrieved at http://www.spacepolitics.com/2009/10/20/lyles-on-constellation-commercialization-and-organization/
[9] Klamper, Amy, "NASA in Limbo as Augustine Panel Issues Final Report," SpaceNews, October 23, 2009, Retrieved at http://spacenews.com/nasa-limbo-augustine-panel-issues-final-report/
[10] See Supra 6
[11] National Aeronautics and Space Administration Authorization Act of 2010 (P.L. 111-267)

destinations."[12] The NASA Transition Authorization Act of 2017 reiterated Congress's support for the stepping stone approach to space exploration and directed NASA to establish a human exploration roadmap.[13] The Act also directed NASA to continue development of SLS and Orion to enable human exploration of the Moon, Mars, and beyond. The following year, NASA issued a National Space Exploration Campaign Report setting forth the "roadmap" requested by Congress, and detailing the Agency's plan for human space exploration, which included a crewed lunar landing by the late 2020s.[14]

During his Administration, President Biden chose to continue the Artemis program, and in late 2021, released a United States Space Priorities Framework that reaffirmed the commitment to send humans to the Moon as a step towards future missions to Mars and other deep space destinations.[15] In 2022, Congress provided further direction to NASA via the CHIPS and Science Act. Specifically, Congress directed NASA to establish a new Moon to Mars Program Office within the Exploration Systems Development Mission Directorate (ESDMD), charged with managing hardware development, mission integration, and risk management for Artemis. The office was also directed to ensure that Artemis activities demonstrated capabilities to facilitate eventual human missions to Mars. [16]

Artemis Elements

The Artemis program involves a number of NASA programs and projects mainly managed within ESDMD, although the Space Technology Mission Directorate (STMD) and Science Mission Directorate (SMD) also manage some elements. Additionally, both the U.S. private sector and international governments are contributing to Artemis in various ways. Core Artemis mission elements include:

Space Launch System (SLS). SLS is a two-stage, super heavy-lift launch vehicle that will launch the Orion spacecraft. NASA plans for three different SLS configurations (Block 1, 1B, and 2) with each configuration resulting in an eventual 130 metric tons to low Earth orbit capability. Between Block 1 and 1B, the Interim Cryogenic Propulsion Stage (ICPS) will be replaced with the Exploration Upper Stage (EUS). Additionally, Block 2 will replace the solid rocket boosters with an upgraded model.

Orion Spacecraft. The Orion multipurpose crew vehicle is a spacecraft capable of supporting crew exploration in deep space for up to 21 days. Orion consists of three main components: a crew module, a service module, and a launch abort system. For Artemis, Orion will carry the crew to lunar orbit and return them safely to Earth.

Exploration Ground Systems (EGS). EGS manages the development and operation of Kennedy Space Center systems and facilities that support modern and next generation launch

[12] President Donald Trump, *Space Policy Directive-1, Reinvigorating America's Human Space Exploration Program,* December 2017. Retrieved at https://trumpwhitehouse.archives.gov/presidential-actions/presidential-memorandum-reinvigorating-americas-human-space-exploration-program/
[13] National Aeronautics and Space Administration Transition Authorization Act of 2017 (P.L. 115-10)
[14] National Aeronautics and Space Administration, *National Space Exploration Campaign Report*, September 2018. Retrieved at https://www.nasa.gov/wp-content/uploads/2015/01/nationalspaceexplorationcampaign.pdf?emrc=dd952c
[15] President Joseph Biden, *United States Space Priorities Framework*, December 2021. Retrieved at https://bidenwhitehouse.archives.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf
[16] CHIPS and Science Act (P.L. 117-167)

vehicles and spacecraft. For Artemis, EGS is responsible for the capabilities used to assemble, launch, and recover SLS and Orion, which includes integration of the SLS and Orion systems in preparation for launch.

Human Landing System (HLS). The HLS is a lunar landing system that will dock either with Gateway or Orion and transport astronauts from lunar orbit to the surface of the Moon and back to lunar orbit. NASA awarded contracts for development of lunar landers to two U.S. commercial providers, SpaceX and Blue Origin.[17]

Gateway. Gateway is a Moon orbiting space station that will provide a staging point for lunar expeditions and deep space exploration, as well as a platform for scientific research and technology demonstrations. NASA plans to launch the first two Gateway modules, the Power and Propulsion Element and Habitation and Logistics Outpost, to create an initial capacity while adding more modules later to expand its capabilities. The Gateway will involve international contributions including additional habitation, external robotics, and refueling capability.

Spacesuits. NASA requires new spacesuits that are suitable for deep space environments, including the lunar surface. While NASA initially planned to produce the suits internally, the agency shifted its acquisition approach and instead opted for a commercial procurement. In June 2022, NASA awarded a contract to Axiom Space to produce new suits for Artemis via the Exploration Extravehicular Activity Services (xEVAS) program.[18]

Artemis Missions

The Artemis program consists of sequentially numbered missions that utilize exploration elements, such as SLS and Orion, to access deep space destinations, including lunar orbit, Gateway, and/or the lunar surface.

[17] National Aeronautics and Space Administration, *About Human Landing Systems Development.* Retrieved at https://www.nasa.gov/reference/human-landing-systems/

[18] National Aeronautics and Space Administration, *NASA Taps Axiom Space for First Artemis Moonwalking Spacesuits,* September 2022. Retrieved at https://www.nasa.gov/news-release/nasa-taps-axiom-space-for-first-artemis-moonwalking-spacesuits/

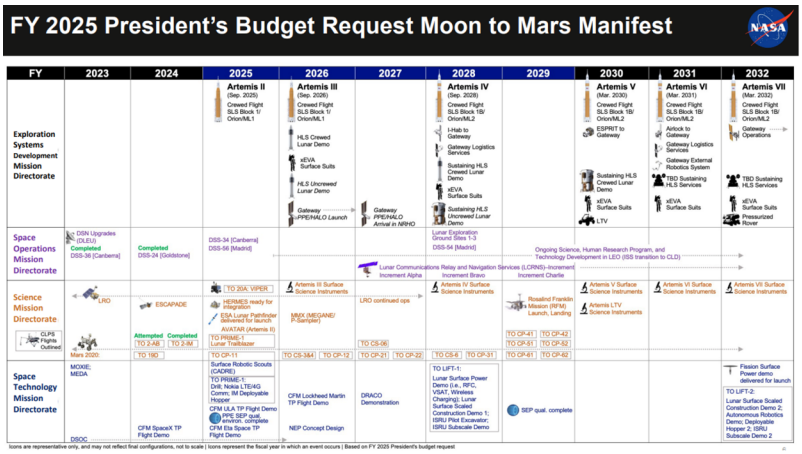

Figure 1: NASA Moon to Mars Manifest. (Source: NASA) [Note: This figure does not reflect the most recent delays for Artemis II and III to April 2026 and mid-2027 respectively.]

Artemis I was an uncrewed demonstration mission that launched out of Kennedy Space Center on November 16, 2022. Originally scheduled for November of 2018, the mission was the first test of the fully integrated SLS, Orion, and EGS systems and conducted two lunar flybys over the course of its 25-day mission before returning to Earth. Post-flight analysis indicated that the mission was successful and many systems performed better than expected,[19] but also flagged issues, including unexpected char loss on the Orion heatshield, that required further investigation.[20]

Artemis II will be the first crewed demonstration flight of the integrated SLS, Orion, and EGS systems. During the mission, which will conduct a flyby of the far side of the Moon, the crew will conduct verification testing on the spacecraft systems and evaluate the spacecraft's performance in deep space. The crew includes NASA astronauts Reid Wiseman, Victor Glover, and Christina Koch as well as Canadian Space Agency astronaut Jeremy Hansen. The mission is currently expected to launch in April 2026.

Artemis III will be a crewed lunar landing demonstration mission and the first crewed mission to the lunar surface. The crew will launch aboard the integrated SLS and Orion spacecraft to a lunar orbit where they rendezvous with the HLS. The HLS will then transport two crew members to the surface for one week during which they will perform a range of tasks including scientific experiments and technology demonstrations. After which, the HLS will return the crew to the Orion spacecraft in lunar orbit before returning to Earth. The mission is currently planned for mid-2027.

---

[19] National Aeronautics and Space Administration, *Analysis Confirms Successful Artemis I Moon Mission, Reviews Continue,* March 2023. Retrieved at https://www.nasa.gov/humans-in-space/analysis-confirms-successful-artemis-i-moon-mission-reviews-continue-2/

[20] National Aeronautics and Space Administration, *NASA Identifies Cause of Artemis I Orion Heat Shield Char Loss,* December 2024. Retrieved at https://www.nasa.gov/missions/artemis/nasa-identifies-cause-of-artemis-i-orion-heat-shield-char-loss/

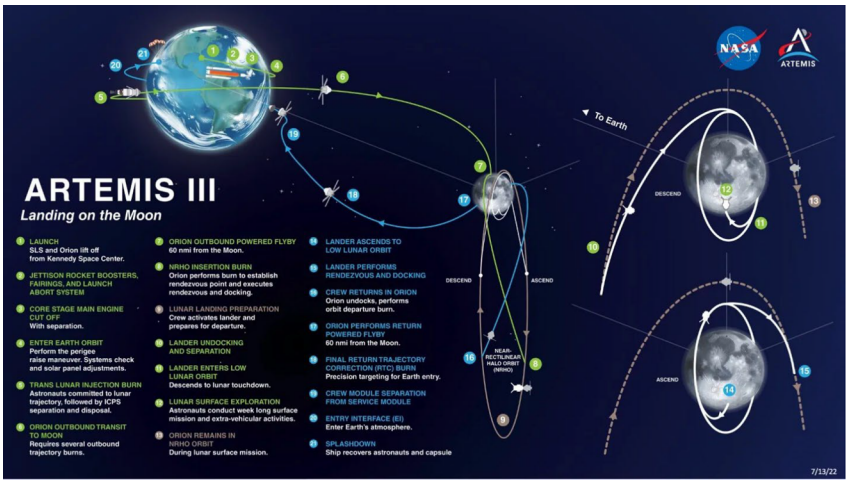

Figure 2: Artemis III Mission Map. (Source: NASA)

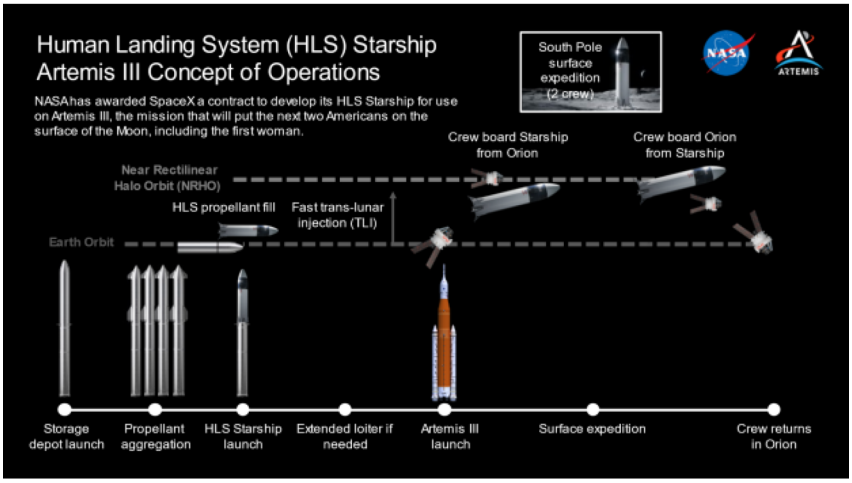

Figure 3: Artemis III HLS Concept of Operations. (Source: NASA)

Artemis IV will be the second crewed lunar landing mission and the debut of the Block 1B variant of SLS. During the mission, Orion will transport the crew as well as the I-Hab module to lunar orbit. The module will then be delivered to Gateway after which two crew members will travel to the lunar surface aboard HLS for a week of surface operations, including sample collection, before returning to Earth.

Artemis V will also use SLS Block 1B to deliver crew to lunar orbit and the ESPRIT module to Gateway. Two astronauts will again travel to the lunar surface abord HLS to collect additional samples for return to Earth.

As the Artemis program progresses, NASA intends to establish an annual launch cadence for SLS with "at least one crewed flight per year for the next 10 or more years."[21] To support this schedule the Agency began to establish long-lead contracts for SLS, including for solid rocket boosters, core stages, and RS-25 engines.

Artemis Budget

The Artemis program is primarily funded through the Deep Space Exploration Systems budget line. The following provides an overview of the budget for the program:

Budget Authority ($ in millions)	Op Plan 2023	CR 2024	Request 2025	2026	2027	2028	2029
NASA Total	**25,383.7**	**25,383.7**	**25,383.7**	**25,891.3**	**26,409.1**	**26,937.3**	**27,476.1**
Deep Space Exploration Systems	**7,447.6**	**7,468.9**	**7,618.2**	**7,803.7**	**7,959.8**	**8,119.0**	**8,281.4**
Moon to Mars Transportation System	**4,716.6**	**--**	**4,213.0**	**4,254.0**	**4,267.3**	**3,880.9**	**3,713.6**
Orion Program	**1,315.1**	**--**	**1,031.0**	**1,176.9**	**1,288.5**	**1,266.4**	**1,166.4**
Crew Vehicle Development	1,301.5	1,221.0	1,023.5	1,141.9	1,281.0	1,213.7	1,113.8
Orion Program Integration and Support	13.5	--	7.5	35.0	7.5	52.7	52.7
Space Launch System	**2,566.8**	**--**	**2,423.2**	**2,379.0**	**2,402.9**	**2,072.3**	**2,026.8**
Block 1B Capability Upgrade	648.3	462.5	285.8	275.1	54.3	--	--
SLS Operations	1,844.4	--	2,028.4	1,972.0	2,240.5	1,899.8	1,853.8
SLS Program Integration and Support	74.0	--	109.0	131.9	108.1	172.5	173.0
Exploration Ground Systems	**834.8**	**--**	**758.8**	**698.1**	**576.0**	**542.3**	**520.4**
Exploration Ground Systems Development	330.6	356.2	235.8	148.3	31.4	--	--
EGS Program Integration and Support	504.2	--	523.0	549.8	544.6	542.3	520.4
Moon to Mars Lunar Systems Development	**2,630.5**	**--**	**3,288.1**	**3,285.7**	**3,389.5**	**3,868.8**	**3,712.3**
Gateway	**779.2**	**--**	**817.7**	**627.9**	**586.8**	**746.0**	**635.4**
Gateway Initial Capability	493.0	516.6	431.8	181.3	--	--	--
xEVA and Human Surface Mobility Program	**324.9**	**--**	**434.2**	**483.9**	**644.7**	**673.6**	**571.2**
Human Landing System	**1,386.1**	**--**	**1,896.1**	**2,050.9**	**1,994.9**	**2,278.3**	**2,334.7**
HLS Initial Capability	807.3	526.3	647.1	703.3	607.2	252.1	--
Advanced Exploration Systems	**140.3**	**--**	**140.2**	**123.0**	**163.1**	**170.9**	**171.0**
Human Exploration Requirements & Architecture	**100.5**	**--**	**117.1**	**264.1**	**303.0**	**369.3**	**855.5**
Strategy & Architecture	**48.3**	**--**	**71.2**	**137.4**	**64.1**	**65.5**	**66.7**
Future Systems	**52.2**	**--**	**45.9**	**126.7**	**238.8**	**303.8**	**788.8**

Figure 4: NASA Fiscal Year 2025 President's Budget Request. (Source: NASA)

[21] National Aeronautics and Space Administration, *NASA Seeks Input to Position Mega-Rocket for Long-Term Exploration,* October 2021. Retrieved at https://www.nasa.gov/missions/artemis/orion/nasa-seeks-input-to-position-mega-rocket-for-long-term-exploration/

Key Issues Identified in Recent Reports, Reviews, and Audits

Government Accountability Office (GAO)

NASA Artemis Missions: Exploration Ground Systems Program Could Strengthen Schedule Decisions[22]

In October 2024, GAO issued a report evaluating NASA management of the EGS program as well as reviewing the impact that EGS delays pose for the Artemis program. The concerns identified by GAO include the following:

- The one-year gap between Artemis II and III creates little schedule margin to mitigate challenges and technical issues as well as take corrective actions between the missions. This is particularly true for the Mobile-Launcher-1 (ML-1), which experienced an unexpected level of damage during the Artemis I launch and must be repaired again between Artemis II and III.

- The Mobile-Launcher-2 (ML-2) is the primary schedule driver for Artemis IV and its development has limited margin and significant risk. Additionally, the majority of the work related to ML-2 can only be accomplished after the launch of Artemis III which creates additional schedule risk. Despite this, NASA has not committed to conducting a schedule risk analysis for EGS and ML2 moving forward.

GAO recommended that NASA direct the Exploration Ground Systems program and Mobile Launcher 2 project officials to perform at least one schedule risk analysis prior to beginning integrated operation activities to support the Artemis IV launch.

NASA Inspector General

NASA's Management of Space Launch System Block 1B Development[23]

NASA Office of Inspector General (OIG) released a report in August 2024 that evaluated NASA's Management of SLS Block 1B development. The report found:

- Boeing's quality management system at Michoud does not effectively adhere to industry standards or NASA requirements which creates production delays to the SLS core and upper stages and increased risk to the integrated spacecraft. This is compounded by a lack of sufficient aerospace production experience among Boeing's Michoud workforce.

- The total costs for SLS Block 1B development are expected to reach $5.7 billion which is $700 million over the cost baseline.

- NASA delayed establishing the Block 1B Agency Baseline Commitment until December 2023, after 10 years of development and much later in the project life cycle than NASA's

[22] Government Accountability Office, *NASA Artemis Missions: Exploration Ground Systems Program Could Strengthen Schedule Decision,* October 2024, GAO-25-106943. Retrieved at https://files.gao.gov/reports/GAO-25-106943/index.html
[23] NASA Office of Inspector General, *NASA's Management of Space Launch System Block 1B Development,* August 2024, IG-24-015. Retrieved at https://oig.nasa.gov/office-of-inspector-general-oig/nasas-management-of-space-launch-system-block-1b-development/

standard practice. This delay limited NASA's ability to assess adherence to budgets and timelines, and Congress lacked visibility into the Block 1B's increasing costs and schedule delays.

NASA's Readiness for the Artemis II Crewed Mission to Lunar Orbit[24]

In May 2024 NASA OIG released a report reviewing NASA's preparedness for Artemis II, particularly given the issues that arose during the Artemis I mission in November 2022. The OIG found that:

- The Orion heat shield experienced unexpected ablative char loss during the Artemis I mission. While the char loss was unanticipated, NASA's post-mission investigation of the heat shield found that "thermal performance of the heat shield exceeded expectations."[25] Additionally, there was unexpected melting and erosion on the Orion Crew Module/Service Module separation bolts which created a gap leading to increased heating inside the bolt.

- NASA recorded 24 instances of power distribution anomalies in Orion's Electrical Power System. The Agency determined radiation was the root cause and is working on corrective actions. However, without a permanent hardware fix there is an increased risk of further power distribution anomalies on future missions.

- During Artemis I, SLS caused greater damage to ML-1 than expected. NASA set aside $5 million for post-Artemis launch repairs, but the actual damage is expected to cost more than $26 million to repair.

The OIG recommended that NASA:

- Ensure the root cause of Orion heat shield char liberation is well understood prior to launch of the Artemis II mission.

- Conduct analysis of Orion separation bolts using updated models that account for char loss, design modifications, and operational changes to Orion prior to launch of the Artemis II mission.

- Reexamine procedures to better ensure recovery of Orion jettisoned hardware for the Artemis II mission.

- Develop a corrective action plan to mitigate or prevent the recurrence of uninterpretable Orion telemetry data for the Artemis II mission

[24] NASA Office of Inspector General, *NASA's Readiness for the Artemis II Crewed Mission to Lunar Orbit,* May 2024, IG-24-011. Retrieved at https://oig.nasa.gov/office-of-inspector-general-oig/audit-reports/nasas-readiness-for-the-artemis-ii-crewed-mission-to-lunar-orbit/

[25] National Aeronautics and Space Administration, *NASA Identifies Cause of Artemis I Orion Heat Shield Char Loss,* December 2024. Retrieved at https://www.nasa.gov/missions/artemis/nasa-identifies-cause-of-artemis-i-orion-heat-shield-char-loss/

- Establish a course of action and timeline for individual Artemis system design changes before beginning integrated system assembly stacking operations.

NASA's Aerospace Safety Advisory Panel

Aerospace Safety Advisory Panel 2024 Annual Report[26]
The Aerospace Safety Advisory Panel (ASAP) is a congressionally mandated NASA advisory committee that conducts an annual review of the safety of NASA activities with a priority focus on human space flight safety. In the 2024 ASAP report, Artemis remained a continued focus.

The Panel raised concerns about the aggregated risk created by the large number of first-time milestones present in the Artemis III mission architecture given the current mission schedule and technical readiness of some elements, particularly HLS. The Panel also noted that NASA will need to craft an approach to Artemis program integration because of the number of service contracts and international contributions to the program and varied roles and responsibilities of each partner.

Additionally, the Panel suggested that NASA could strengthen Artemis Architectural Completeness and Risk Management. This includes formalizing a Design Reference Mission to define how a mission will be conducted, specifying objectives, the systems involved, and operational processes. As well as defining key mission objectives for each Artemis mission and ensuring the objectives are balanced across the program.

[26] NASA Aerospace Safety Advisory Panel, *2024 Annual Report,* February 2025. Retrieved at https://www.nasa.gov/asap-reports/

Chairman HARIDOPOLOS. The Subcommittee on Space and Aeronautics will come to order. Without objection, the Chair is authorized to declare recess of the Subcommittee at any time. Welcome to today's hearing entitled "Step by Step: The Artemis Program and NASA (National Aeronautics and Space Administration)'s Path to Human Exploration of the Moon, Mars, and Beyond." And with that, I recognize myself for 5 minutes for an opening statement.

Welcome to the Space and Aeronautics Subcommittee's first hearing of the 119th Congress. I extend my warm welcome to our Ranking Member, Congresswoman Foushee from the State of North Carolina, and express my enthusiasm to work with her and her team and the returning Members of this Subcommittee.

2026 will be a defining year for the legacy of the United States. Next April, NASA is set to launch Artemis II, a mission sending American astronauts into orbit around the Moon for the first time in 50 years. If we succeed, we will clear the path for Artemis III in 2027 when American astronauts will once again step onto the lunar surface and plant the Stars and Stripes. This is the most significant moment of America's space program since the Apollo program.

We stand at a crossroads. The world is watching, and our competitors, like communist China, are racing to beat us there. We cannot afford to fall behind. This is an opportunity to prove that America still leads the world in exploration and innovation. Failure is not an option.

To succeed, we need the same relentless pace and ironclad determination today as we won the space race back in the 1960's. With each mission, NASA tested new systems, tackled new challenges, and carried us one step closer to Neil Armstrong's great giant leap for mankind.

At the height of the Apollo program, NASA launched seven crewed missions in less than 2 years. That achievement was fueled by patriotism, urgency, ingenuity, and an unshakable belief in American greatness.

Returning to the Moon has not been without its challenges. Over the years, changing directions and requirements have resulted in schedule delays and cost overruns. Not only must we return to the Moon and establish a presence, but we must do it while spending significantly less money than the Apollo missions. That makes every taxpayer dollar given to NASA precious.

We aim to get the Artemis program back on track. Thanks to President Trump, NASA has a clear direction now that we must ensure that NASA carries out that direction in the most efficient and cost-effective means possible. I plan to conduct those—I plan to conduct close oversight to ensure that every dollar NASA spends moves us closer to the Moon and to Mars.

We must remember that we are in a race to the Moon and that there are consequences for coming in second. The Chinese Communist Party (CCP) has set its sights on landing on the Moon by 2030. The Nation must establish a foothold there and will shape the norms of behavior for generations of exploration on the lunar surface. I refuse to let the communist dictatorship set the rules for the future of space. Now is not the time for half measures, and the next few years are critical to our national interests and our place

in the world. We are on—in a race to the Moon, and America must win that race.

Our journey to the Moon is in service to a greater goal, one that President Trump outlined in his inaugural address, to plant the Stars and Stripes on the planet Mars. Since 2005, Congress has backed a step-by-step path to human exploration with Mars as the ultimate goal. A mission to Mars will be the defining moment of our era. It will no longer—and even—it will be longer and even more difficult than a lunar landing, which is why we must prepare ourselves for the journey. The Moon is our critical steppingstone, a proving ground to test technologies, refine operations, and reduce risks for future Mars missions. Every step we take toward the Moon is a giant leap toward Mars.

To my fellow Americans, you deserve to know where your dollars are spent wisely. We will conduct careful oversight to ensure that NASA operates at the highest standards, and we will settle for nothing less than efficiency, productivity, and results. This is a chance to remind ourselves that we are capable—what we are capable of when we are united behind a shared goal. Mars is on the horizon, but the Moon is where we first prove ourselves.

I want to thank our witnesses for joining us today, and let's get to work.

[The prepared statement of Chairman Haridopolos follows:]

Welcome to the Space and Aeronautics Subcommittee's first hearing of the 119th Congress.

I extend a warm welcome to Ranking Member Foushee and express my enthusiasm to work with both new and returning members of this subcommittee.

2026 will be a defining year for the legacy of the United States.

Next April, NASA is set to launch the Artemis 2 mission, sending American astronauts into orbit around the Moon for the first time in fifty years.

If we succeed, we will clear the path for Artemis 3 in 2027, when American astronauts will once again step onto the lunar surface and plant the Stars and Stripes.

This is the most significant moment for America's space program since the Apollo program.

We stand at a crossroads: The world is watching, and our competitors—like Communist China—are racing to beat us there.

We cannot afford to fall behind, this is an opportunity to prove that America still leads the world in exploration and innovation.

Failure is NOT an option.

To succeed, we need the same relentless pace and ironclad determination today that won us the Space Race in the 1960s.

With each mission, NASA tested new systems, tackled new challenges, and carried us one step closer to Neil Armstrong's giant leap for mankind.

At the height of the Apollo Program, NASA launched seven crewed missions in less than two years.

That achievement was fueled by patriotism, urgency, ingenuity, and an unshakable belief in American greatness.

Returning to the Moon has not been without its challenges.

Over the years, changing directions and requirements have resulted in schedule delays and cost overruns.

Not only must we return to the Moon and establish a presence, but we must do it while spending significantly less money than the Apollo missions.

That makes every taxpayer dollar given to NASA precious.

We aim to get the Artemis program back on track.

Thanks to President Trump, NASA has clear direction. Now, we must ensure that NASA carries out that direction in the most efficient and cost-effective way possible.

I plan to conduct close oversight to ensure that every dollar NASA spends moves us closer to the Moon and to Mars.

We must also remember that we are in a race to the Moon, and that there are consequences for coming in second.

The Chinese Communist Party has set its sights on landing on the Moon by 2030.

The nation to establish a foothold there will shape the norms of behavior for generations of exploration on the lunar surface.

I refuse to let a communist dictatorship set the rules of the road for the future of space.

Now is not a time for half-measures. The next few years are critical to our national interests and our place in the world.

We are in a race to the Moon, and America must win that race.

Our journey to the Moon is in service to a greater goal, one that President Trump outlined in his inaugural address: "To plant the Stars and Stripes on the planet Mars".

Since 2005, Congress has backed a step-by-step path to human exploration, with Mars as our ultimate goal.

A mission to Mars will be the defining moment of our era.

It will be longer and even more difficult than a lunar landing, which is why we must prepare ourselves for the journey.

The Moon is our crucial stepping stone—a proving ground to test technologies, refine operations, and reduce risks for that future Mars mission.

Every step we take towards the Moon is a giant leap towards Mars.

To my fellow Americans, you deserve to know your dollars are spent wisely. We will conduct careful oversight to ensure that NASA operates at the highest standards, and we will settle for nothing less than efficiency, productivity, and results.

This is a chance to remind ourselves what we're capable of when we unite behind a shared goal.

Mars is on the horizon, but the Moon is where we first prove ourselves.

I thank our witnesses for joining us today. Let's get to work.

Chairman HARIDOPOLOS. With that, I would like to recognize our Ranking Member from the State of North Carolina, Congresswoman Foushee, and you're recognized.

Mrs. FOUSHEE. Thank you, Mr. Chairman. I am thrilled to serve as Ranking Member of the Subcommittee on Space and Aeronautics. We are at an exciting time, and I look forward to working with you and the Members of the Subcommittee and full Committee to continue our bipartisan and critical work on ensuring a strong and vibrant future for civil space and aeronautics.

Before we turn to the hearing, I want to first welcome our expert witnesses and thank you for being here to discuss Artemis and NASA's human exploration of the Moon, Mars, and beyond.

Through the Artemis initiative, we'll land the first woman, first person of color, and the first international partner astronaut on the surfaces of the Moon. And I am so proud that Christina Koch, who attended high school in my district, North Carolina's 4th, will be a part of this historic Artemis II crew, marking the first return of humans to the lunar vicinity in over half a century.

Artemis will advance our scientific understanding, test capabilities needed for sustained lunar activities, assess resources on the Moon, and help us prepare for an eventual groundbreaking human mission to Mars. Artemis is also attracting commercial innovation to advance these and other U.S. lunar activities. Importantly, under Artemis, the United States of America, in hand with our international partners, will lead and shape standards, responsible behaviors, and best practices consistent with the peaceful exploration and safe utilization of outer space.

In 2022 NASA successfully launched the Artemis I uncrewed demo mission that provided essential test data, including on the Orion heat shield. Artemis II preparations are well underway for a crewed demonstration to fly by the far side of the Moon next year. Even today, as we are holding this hearing, a NASA-supported commercial lunar lander, the second to launch in just 2 months, is sitting on the launchpad ready to lift off. Both commer-

cial landers carry NASA instruments and will attempt to set down on the lunar surface in early March.

Despite these important milestones, NASA's Artemis campaign is not without challenges, including technical complexities, affordability, and schedule delays. We can and we must seek improvements and corrections—and I mean with a scalpel, not a chainsaw—if we are serious about returning to the Moon with humans successfully again. It will take all of us working together to achieve regular, measurable progress and to ensure that it is done so safely.

To that end, I am disappointed that NASA chose not to send a witness to testify today, despite being invited. I certainly hope such practice does not continue. Full transparency with Congress and the American public on an effort as important as Artemis is of the utmost importance.

But these are not normal circumstances. At a time when China is laser focused on sending taikonauts to the Moon by 2030, I cannot pretend today that the chaos, confusion, and cruelty levied on our Federal Government workforce by the Trump Administration and its destructive Executive actions, including the threat of mass firings, will not negatively impact the United States and our standing around the world or its efforts to return our astronauts, American astronauts, to the surface of the Moon, and to do so before China.

I will not sit idly by and let our Federal Government, including NASA, a national crown jewel, be destroyed, nor will I stand for handing the keys to lunar exploration to China. Doing so jeopardizes our economic and national security and our geopolitical influence. It also risks the space research technology and services on which we rely on here on Earth. We must protect and enable these essential capabilities as we also seek to push the boundaries of human exploration and activity beyond low-Earth orbit.

To the NASA workforce, I want you to know that you are valued. We cannot accomplish NASA's inspiring and historic national endeavors without you. As the Ranking Member of this Subcommittee, I commit to keeping NASA workforce top of mind as we work to reauthorize NASA. You are our most important national asset.

Thank you, Mr. Chair, and I yield back.

[The prepared statement of Mrs. Foushee follows:]

Thank you, Mr. Chairman. I am thrilled to serve as Ranking Member of the Subcommittee on Space and Aeronautics. We are at an exciting time, and I look forward to working with you and the Members of the Subcommittee and Full Committee to continue our bipartisan and critical work on ensuring a strong and vibrant future for civil space and aeronautics. Before we turn to the hearing, I want to first welcome our expert witnesses and thank you for being here to discuss Artemis and NASA's human exploration of the Moon, Mars, and Beyond.

Through the Artemis initiative, we'll land the first woman, first person of color, and the first international partner astronaut on the surface of the Moon. And I'm so proud that Christina Koch, who attended high school in my District, North Carolina's Fourth, will be part of the historic Artemis II crew, marking the first return of humans to the lunar vicinity in over a half-century. Artemis will advance our scientific understanding, test capabilities needed for sustained lunar activities, assess resources on the moon, and help us prepare for an eventual, groundbreaking human mission to Mars. Artemis is also attracting commercial innovation to advance these and other U.S. lunar activities.

Importantly, under Artemis, the United States of America, in hand with our international partners, will lead and shape standards, responsible behaviors, and best practices consistent with the peaceful exploration and safe utilization of outer space. In 2022, NASA successfully launched the Artemis I uncrewed demo mission that provided essential test data, including on the Orion heat shield. Artemis II preparations are well underway for a crewed demonstration to flyby the far side of the moon next year.

Even today, as we hold this hearing, a NASA-supported commercial lunar lander—the second to launch in just two months—is sitting on the launch pad ready to lift off. Both commercial landers carry NASA instruments and will attempt to set down on the lunar surface in early March.Despite these important milestones, NASA's Artemis campaign is not without challenges, including technical complexities, affordability, and schedule delays.

We can and we must seek improvements and corrections—and I mean with a scalpel not a chainsaw—if we are serious about returning to the Moon with humans successfully again. It will take all of us working together to achieve regular, measurable progress, and to ensure that it is done so safely. To that end, I am disappointed that NASA chose not to send a witness to testify today, despite being invited. I certainly hope such practice does not continue. Full transparency with Congress and the American public on an effort as important as Artemis is of the upmost importance.

But these are not normal circumstances. At a time when China is laser focused on sending taikonauts to the Moon by 2030, I cannot pretend today that the chaos, confusion, and cruelty levied on our Federal government workforce by the Trump Administration and its destructive executive actions—including the threat of mass firings—will not negatively impact the United States and our standing around the world, or its efforts to return our astronauts, American astronauts, to the surface of the Moon, and to do so before China.

I will not sit idly and let our federal government, including NASA—a national crown jewel—be destroyed. Nor will I stand for handing the keys to lunar exploration to China. Doing so jeopardizes our economic and national security, and our geopolitical influence. It also risks the space research, technology, and services on which we rely here on Earth. We must protect and enable these essential capabilities as we also seek to push the boundaries of human exploration and activity beyond low Earth orbit.

To the NASA workforce, I want you to know that you are valued. We cannot accomplish NASA's inspiring and historic national endeavors without you. As Ranking Member of this Subcommittee, I commit to keeping the NASA workforce top of mind as we work to reauthorize NASA. You are our most important national asset.

Thank you Mr. Chair, and I yield back.

Chairman HARIDOPOLOS. Thank you, Ranking Member Foushee. Also for the record, before we move on, I would like to request unanimous consent to submit two letters for the record. The first is from Space Frontier Foundation, and the second is from Coalition for Deep Space Exploration. Without objection, so ordered.

Next, I would of course like to welcome our Chairman, Chairman Babin. Thank you very much for being here. And with that, I recognize the Chairman for his remarks.

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

After serving at the helm of this Subcommittee for so many years, it's going to take a hearing or two to get used to sitting way down here at this end. But today's hearing is especially important as America stands on the verge of returning to the lunar surface. And as the proud Representative of NASA's Johnson Space Center, it is also a topic that is very near and dear to me.

Space exploration is not a task for the faint of heart. American astronauts have accomplished great feats in space. They have built space stations, operated the space shuttle, and, of course, walked on the Moon. However, these programs are significant undertakings, both in time and in resources. In 2005, Congress directed NASA to develop a sustained human presence on the Moon as a steppingstone to future exploration of Mars and other destinations.

The name and format of the program NASA would use to accomplish this goal changed with time, but in each of the authorization acts that followed over the years, Congress consistently directed NASA to pursue an incremental approach using intermediate destinations to develop extensible technologies that would enable humans to explore the Moon, Mars, and beyond.

Given the time—and resource—intensive nature of any space mission, successfully carrying out a crewed space exploration program requires that the government maintain continuity of purpose over the course of several years. Changing direction isn't free, and it is incredibly taxing on the United States' industrial base. For years, as it evolved from the Constellation program to SLS (Space Launch System) and Orion, even to an asteroid redirect mission, America's space program has lacked a clear and consistent path.

And that is why I was honored to be at the President—at President Trump's side when he signed Space Policy Directive 1, more commonly known as SPD–1, in December 2017. This update to United States' national space policy instructed NASA to partner with the commercial sector and international community to return humans to the Moon and eventually push toward Mars. SPD–1 aligned with the congressional direction set forth in previous NASA authorization bills and outlined a clear, reachable goal that injected a new sense of urgency and excitement into NASA's mission. To ensure the viability of the Artemis program and the efforts of our commercial and international partners, Congress cannot accept unnecessary cost overruns or scheduled delays. We will continue to evaluate the proposed architecture regularly and provide rigorous oversight to ensure that the program remains on track.

With the CCP planning to send taikonauts to the Moon's South Pole by the end of this decade, the stakes are too high for us to fail. We cannot afford to let them beat us. And as I've stated many, many times before, one of my greatest concerns is that NASA astronauts will arrive on the lunar surface only to be greeted by a sign that says "no trespassing" in Mandarin.

Our Nation is uniquely suited to provide leadership on the Moon with our commercial and international partners, and additionally, the United States will maintain openness and transparency in its operations on the lunar surface, something that we can be certain the CCP will not.

We came close to sending a NASA authorization bill to the President's desk late last year. Soon, this Committee will once again consider legislation to provide NASA with continued direction for human exploration and many other topics. I look forward to working with my colleagues on the Committee and our counterparts in the Senate to finish the job this year.

We have a great panel of witnesses, and I want to thank both of them for being here today, who are no strangers to this Committee. And I thank them for sharing their expertise with us, and I look forward to a very productive discussion today.

And with that, I yield back, Mr. Chairman.

[The prepared statement of Chairman Babin follows:]

Thank you, Mr. Chairman. After serving at the helm of this subcommittee for so many years, it might take a hearing or two to get used to sitting at this end of the dais!

Today's hearing is especially important as America stands on the verge of returning to the lunar surface. And as the proud Representative of NASA's Johnson Space Center, it is also a topic near and dear to me.

Space exploration is not a task for the faint of heart. American astronauts have accomplished great feats in space: They have built space stations, operated the space shuttle, and, of course, walked on the Moon. However, these programs are significant undertakings, both in time and resources.

In 2005, Congress directed NASA to develop a sustained human presence on the Moon as a stepping-stone to future exploration of Mars and other destinations. The name and format of the program NASA would use to accomplish this goal changed with time, but in each of the authorization acts that followed over the years, Congress consistently directed NASA to pursue an incremental approach, using intermediate destinations to develop extensible technologies that would enable humans to explore the Moon, Mars, and beyond.

Given the time and resource intensive nature of any space mission, successfully carrying out a crewed space exploration program requires that the government maintain continuity of purpose over the course of several years.

Changing direction isn't free and is incredibly taxing on the United States industrial base. For years, as it evolved from the Constellation program, to SLS and Orion, even to an asteroid redirect mission, America's space program lacked a clear and consistent path.

That is why I was honored to be at President Trump's side when he signed Space Policy Directive-1, more commonly known as SPD–1 in December 2017. This update to U.S. national space policy instructed NASA to partner with the commercial sector and international community to return humans to the Moon, and eventually push forward to Mars.

SPD–1 aligned with the congressional direction set forth in previous NASA authorization bills and outlined a clear, reachable goal that injected a new sense of urgency and excitement into NASA's mission.

To ensure the viability of the Artemis program, and the efforts of our commercial and international partners, Congress cannot accept unnecessary cost overruns or schedule delays.

We will continue to evaluate the proposed architecture regularly and provide rigorous oversight to ensure the program remains on track.

With the CCP planning to send taikonauts to the Moon's South Pole by the end of the decade, the stakes are too high for us to fail.

We cannot afford to let them beat us. As I've stated many times before, one of my greatest concerns is that NASA astronauts will arrive at the Moon only to be greeted with a sign that says "No Trespassing" in Mandarin.

Our nation is uniquely suited to provide leadership on the Moon with our commercial and international partners.

Additionally, the U.S. will maintain openness and transparency in its operations on the lunar surface—something we can be certain the CCP will not.

We came close to sending a NASA authorization bill to the President's desk late last year. Soon, this Committee will once again consider legislation to provide NASA with continued direction for human exploration and many other topics. I look forward to working with my colleagues on the Committee and our counterparts in the Senate to finish the job this year.

We have a great panel of witnesses who are no strangers to this Committee. I thank them for sharing their expertise with us and look forward to a productive discussion today.

Chairman HARIDOPOLOS. Thank you, Mr. Chairman.

And now I recognize the Ranking Member of the full Committee for a statement. Thank you, Ranking Member Lofgren. You are recognized.

Ms. LOFGREN. Well, thank you, Chairman Haridopolos and Ranking Member Foushee, for holding this hearing to review NASA's Artemis initiative. And I want to welcome the witnesses back to the Committee. We appreciate you being here.

We're all excited about NASA's Artemis campaign, and we support our Moon to Mars program, and we want the United States to succeed in reestablishing a lunar program in preparation for the even more ambitious goal of being the first to step foot on Mars.

Congress has, through successive NASA authorization acts reaffirmed a continuity of purpose for our Nation's human exploration activities, providing a steady hand in directing a stepping-stone approach to human exploration of the Moon, Mars, and even beyond. While important, continuity of purpose alone will not get us to the Moon and Mars. NASA needs sufficient resources, the necessary workforce and skills, safe and modern infrastructure and facilities, and a viable Artemis architecture couched in technical confidence.

With each of these requirements, I'm afraid there are more questions than answers. We don't know NASA's funding levels after the continuing resolution runs out on March 14, just a short few days from now, and whether it will continue at Fiscal Year 2024 levels or under a Fiscal Year 2025 appropriation. We don't know if NASA will have the workforce and skills to advance Moon to Mars after President Trump's wrecking ball of destructive Executive actions that has led to deferred resignations, threats of layoffs, and a remaining NASA workforce that may be scared, distracted, and demoralized.

We don't know when a Trump Administration Fiscal Year 2026 budget proposal that lays out the Administration's priorities and proposed funding for NASA will arrive and whether it will include funding to rebuild aging and unsafe infrastructure or modernized research facilities. And we don't know when the agency will have a Senate-confirmed Administrator and Deputy Administrator to articulate the Trump Administration's priorities for NASA.

Finally, we don't know if Artemis III and the future human landing approaches, with their highly complex human landing systems and low technical readiness levels, could be viable on a timeframe that will ensure NASA astronauts land at the lunar South Pole and return safely to Earth, we hope in advance of China's taikonauts.

With that, Mr. Chairman, I do hope you will consider holding another hearing once we have a NASA official to testify and the remaining pieces of the puzzle that I've just listed. And with that, Mr. Chairman, I look forward to our witnesses' testimony and their insights. Thank you, and I yield back.

[The prepared statement of Ms. Lofgren follows:]

Good morning. Thank you, Chairman Haridopolos and Ranking Member Foushee for holding this hearing to review NASA's Artemis initiative. Welcome back to both of our distinguished witnesses and thank you for being here today.

I'm excited about NASA's Artemis campaign. I support our Moon to Mars program, and I want the United States to succeed in reestablishing a lunar program in preparation for the even more ambitious goal of being the first nation to step foot on Mars.

Congress has, through successive NASA authorization acts, reaffirmed a continuity of purpose for our nation's human exploration activities, providing a steady hand in directing a stepping- stone approach to human exploration of the Moon, Mars, and beyond.

While important, continuity of purpose alone will not get us to the Moon and Mars. NASA needs sufficient resources, the necessary workforce and skills, safe and modern infrastructure and facilities, and a viable Artemis architecture couched in technical confidence.

With each of these requirements, I'm afraid there are more questions than answers.

We don't know NASA's funding levels after the continuing resolution runs out on March 14th and whether it will continue at fiscal year 2024 levels, or under a fiscal year 2025 appropriation.

We don't know if NASA will have the workforce and skills to advance Moon to Mars after PresidentTrump's wreaking ball of destructive executive actions has led to deferred resignations, threats of layoffs, and a remaining NASA workforce that one could imagine may be scared, distracted, and demoralized.

We don't know when a Trump Administration fiscal year 2026 budget proposal that lays out the Administration's priorities and proposed funding for NASA will arrive, and whether it will include funding to rebuild aging and unsafe infrastructure or modernize research facilities.

We don't know when the agency will have a Senate confirmed Administrator and Deputy Administrator to articulate the Trump Administration's priorities for NASA.

Finally, we don't know if the Artemis III and future human landing approaches, with their highly complex human landing systems and low technical readiness levels could ever be viable on a timeframe that will ensure NASA astronauts land at the lunar south pole and return safely to Earth in advance of China's taikonauts.

With that, Mr. Chairman, I do hope you will consider holding another hearing once we have a NASA official to testify and the remaining pieces of the puzzle that I listed.

I look forward to our witnesses' testimony and insights. Thank you, and I yield back.

Chairman HARIDOPOLOS. Thank you, Ranking Member.

Let me next introduce our witnesses today. Our first witness today is Dr. Scott Pace, the Director of Space Policy Institute at George Washington University. And our next witness is Dr. Daniel Dumbacher, who serves as an Adjunct Professor at Purdue University.

I now recognize Dr. Pace for 5 minutes to present his testimony. You're recognized.

TESTIMONY OF DR. SCOTT PACE, DIRECTOR OF SPACE POLICY INSTITUTE, GEORGE WASHINGTON UNIVERSITY

Dr. PACE. Chairman Haridopolos, Ranking Member Foushee, and distinguished Members of this Subcommittee, thank you very much for holding this important hearing.

As maybe a point of personal interest, I'd also like to acknowledge my friend George Whitesides, newly elected to this Congress, so—he's making me feel old. I remember when we were both much younger in the space advocacy community. But congratulations, sir.

As a new Congress and a new Administration provide a timely opportunity to consider the American space enterprise, and in particular, the role of human space exploration in service of U.S. national interests. I have a written statement I ask permission to be included in the hearing record and will endeavor to keep my remarks brief.

We know space is vitally important to the United States, but the space domain is not subject to the kind of direct control possible with land, sea, or air domains. So how can the United States protect its interests and values? The answer, in part, is through international leadership. During the Apollo era, we sought to show what the United States and only the United States could do in space. Today, leadership is about having other countries wanting to work with you, to be a partner in common endeavors. We need to shape activities in the space domain in a manner conducive to the interests of the United States, its allies, and like-minded partners.

Space exploration is expensive and takes effort over many years. Space policy, therefore, needs to be consistent and sustainable, and to do so, that policy must be in line with enduring national inter-

ests. I do—I believe we have good space policies today, but we face serious implementation challenges. The immediate challenges for U.S. space exploration include ensuring more than one way of getting Americans to orbit, managing the end of the International Space Station (ISS), enabling one or more private space stations, creating a sustainable return to the Moon, and building the capabilities to place Americans on Mars.

I'd like to share two concerns for human space exploration. First, we should pay attention to geopolitical considerations and competition in order to ensure that our efforts support those larger national interests. The Artemis program is not a military program, but it supports national security purposes by shaping the way nations behave in space. The rules of the space environment will be made by those who show up, not those who stay behind.

The United States landed on the Moon over 55 years ago, but today, we are at risk of seeing Chinese astronauts on the Moon before we're able to return. But more than being first, we need to have a sustainable lunar presence, sustainable technically, economically, politically. Norway was the first to reach the South Pole, but today, it is the United States that puts some 3,000 people on the ice each year. And through its presence, the United States shapes and guides the Antarctic Treaty System for that remote continent today.

Second, for the U.S. leadership to be effective, human space exploration missions cannot be one and done but must be repeatable and sustainable with continuous presence as the norm. These conditions lead to space architecture through elements that are routinely reusable—in-space utilities, power, communications, navigation, advanced biomedical knowledge, and the use of in-space resources such as water ice in asteroids. The technologies and practices needed for Mars can and should benefit operations in low-Earth orbit and the Moon.

The current Artemis program presents many challenges. A primary concern is the Space Launch System, which is expensive and not reusable. It's had one flight but has trouble meeting the congressional target of two cores per year. It's time to consider alternatives for going from the earth to the Moon and back. Ideally, NASA should be able to buy heavy lift services to send payloads to the Moon.

A revised Artemis campaign plan should be a high priority for the new Administrator. There may be some painful adjustments with industry and our international partners, but—excuse me—but it's better to do so now than to continue on an unsustainable and unaffordable path. The Artemis policy is a good one, supported by Congress and multiple Administrations. However, we need a more sustainable and credible approach to maintain the confidence of the White House, Congress, industry, and our international partners.

Thank you for your kind attention, and I look forward to your questions.

[The prepared statement of Dr. Pace follows:]

House Committee on Science, Space, and Technology
February 26, 2025 – 10 am

Statement for the Record
Scott Pace
Director, Space Policy Institute
Elliott School of International Affairs

Chairman Haridopolos, Ranking Member Foushee, and distinguished members of this Subcommittee. Thank you for holding this important hearing.

A new Congress and a new Administration provide a timely opportunity to consider the American space enterprise – and in particular, the role of human space exploration in service to U.S. national interests.

I have a written statement that I ask your permission to be including in the hearing record but will endeavor to keep my oral statement brief.

Recent History

After the loss of the Space Shuttle *Columbia* in 2003, the United States chose to complete the International Space Station, retire the Shuttle program, and set a new direction for human space missions beyond the Earth, first the Moon, then Mars. The Congress passed back to back, bipartisan NASA authorization bills in 2005 and 2008. Such consistent, bipartisan support is incredibly important to long-term efforts such as space exploration.

NASA took a detour during the Obama Administration, with the deletion of human lunar return and its replacement with an Asteroid Retrieval Mission and an ill-defined, unilateral "Journey to Mars." On a bipartisan basis, members of Congress were uncomfortable with the new direction from the White House, leading to a very contentious fight over the 2010 NASA authorization bill.

While a fan exploring Mars and asteroids, I was also opposed to the "Journey to Mars" concept as it lacked a clear program and did not provide a meaningful path for international or commercial participation. As a result, you could see other countries withdrawing from us, leading to geopolitical harm to U.S. interests in space. In 2017, the Trump Administration issued Space Policy Directive 1, which reflected a return to the bipartisan consistency of the Moon then Mars. SPD-1 also recognized the necessity of international and commercial partnerships, both of which had become far more capable than the Moon-Mars proposals for the Bush 41 and Bush 43 Administrations (i.e., the Space Exploration Initiative, and the Vision for Space Exploration, respectively).

We know space is vitally important to the United States. But the space domain is not subject to the kind of direct control possible with land, sea or air domains. So how can the United States protect its interests and values? The answer, in part, is through international leadership. International leadership in space today is different than during the Apollo era. Sixty years ago, the point was to show what the United States, and only the United States could do. Today, space leadership is about having other countries wanting to work with you, to be a partner in common endeavors. In doing so, we can shape activities in the space domain in a manner conducive to the interests of the United States, its allies, and like-minded partners.

A sustainable space policy is one which is aligned with enduring national interests, not a particular party or personality. In signing SPD-1 in 2017, President Trump said "Beginning with missions beyond low Earth orbit, the United States will lead the return of humans to the Moon for long term exploration and utilization, followed by human missions to Mars and other destinations." This direction is technically sound in its inclusion of both the Moon and Mars in U.S. human space exploration objectives. It is practical in its reliance on commercial partnership and innovation. Finally, it is geopolitically sound in its use of international cooperation to shape the environment upon which the United States relies and in which it competes.

President Reagan's 1988 National Space Policy said that the goal of human space exploration was to "to expand human presence and activity beyond Earth orbit into the solar system." In doing so, the United States would not be choosing between humans or robots. We need both. We would not be choosing either the Moon or Mars. We need both. President Reagan's direction, like President Trump's, was not about "flags and footprints" but about the expansion of humanity and the United States in particular. The nation conducts dangerous and expensive exploration missions to advance the interests and values of the United States. Such missions should be conducted in a way that enhances our security, strengthens our economy, encourages others to align with us and our values, gains knowledge and skills and inspires the next generation.

Immediate Challenges

There are several immediate challenges for U.S. space exploration, such as ensuring more than one way of getting Americans to orbit, managing the end of the International Space Station and transitioning to one or more private platforms, creating a sustainable return to the Moon, and building the capabilities needed to place Americans on Mars and return them safely to Earth.

For over twenty years, Mars has been the official goal of U.S. human space exploration and this is reflected in the current National Space Policy of 2020. Nonetheless, more can be done to advance Mars exploration. There are planetary launch "windows" in 2026 and the last quarter of 2028/first quarter of 2029. Elon Musk has said he will try to land unmanned Starships on Mars using the first. If successful, he would try for a crewed mission using the second window. I am clearly not Elon Musk, but I do see one-way, unmanned landings as feasible while I am skeptical of a successful human landing on Mars in the next five years. At the extreme, a robotic

return Mars soil samples or a human fly-by of Mars (like the Apollo 8 mission to the Moon) may become feasible.

While thinking about Mars missions, we should be mindful of China. They have their own space station, they have landed robots on the Moon and Mars, and they are planning to put humans on the Moon and return samples from Mars. It is entirely possible that they could beat us in achieving these latter two tasks.

The United States landed on the Moon over 55 years ago. But we should not want to see China on the Moon before we're able to return. More importantly, we need to be able to have a sustainable lunar presence – sustainable technically, economically, and politically. Norway was the first to reach the South Pole, but today it is the United States that puts some 3,000 persons "on the ice" each year. Through its presence, the United States shapes and guides the Antarctic Treaty System for that remote continent today.

As a consequence, I'd like to share two concerns for U.S. human space exploration. First, we should pay attention to geopolitical conditions and competition in order to ensure our space efforts support our larger national interests. Second, for U.S. leadership to be effective, human space exploration missions cannot be "one and done" but must be repeatable and sustainable, with continuous presence as the norm. These conditions lead to space architectures whose elements are reusable, with in-space utilities for power, communications, and navigation, advanced biomedical knowledge, and the use of in-space resources (e.g., lunar water ice, asteroids).

The current Artemis program presents very complex challenges, especially for the systems engineering and integration required to incorporate commercial and international partner contributions. A primary concern is the Space Launch System (SLS), which is not reusable. It has had one flight, but has trouble supporting one flight per year, much less congressional targets of two "cores" per year. A second mobile launch platform (MLP-2) and the Exploration Upper Station for the SLS Block 2 are behind schedule. Cores for the Artemis 2 and Artemis 3 missions, involving crews flying around the Moon and then landing, are well along. But it is time to consider alternatives for going from the Earth to the Moon and returning.

We need an off-ramp for reliance on the SLS. Ideally, NASA should be able to buy heavy lift services to send payloads to the Moon – up to about 45 metric tons to "trans-lunar injection" which is about the same performance as the SLS Block 2. I was a supporter of SLS when it was created as NASA required heavy-lift vehicles to send humans to the Moon and Mars. At the time, it did not appear (to me) that a private sector heavy-lift vehicle would be feasible within two decades. Today, the situation is different, with heavy-lift options from SpaceX, Blue Origin, and United Launch Alliance.

A revised Artemis campaign plan should be a high priority for the new NASA Administrator. There may be some painful adjustments with industry and our international partners, but it is better to do so now than to continue on an unsustainable, unaffordable path. The Artemis

policy is a good one, supported by Congress and multiple administrations. However, we need a more sustainable and credible approach so that NASA, industry, and our international partners can make good decisions.

The need for reassessing a major space program is not unique. In 1993, the Space Station Freedom program survived by only one vote in the House. The Clinton Administration came close to cancelling the program but instead chose to partner with Russia in what became the International Space Station. The policy goal of having a space station did not change, but how it was implemented changed drastically. Today, the Artemis program can and should be reformed to fulfil the policy goals of SPD-1. This time, instead of the Russians, we can benefit from a powerful and innovative U.S. private sector and allied spacefaring powers such as Japan and Europe.

NASA needs to focus on those things that make no sense for the private sector to do while using the private sector to improve what NASA does. NASA has critical roles to play in science, technology development for unique, government missions, and developing infrastructure. Through lunar operations, we will build experience and capacity for Mars. The creation of private communications, navigation, and power systems on and around the Moon will feed forward to Mars. New nuclear power sources, a solar system wide internet and the use of local resources can make habitation of the Moon and Mars as sustainable as being in Antarctica is today.

We are and have been headed to Mars. We can certainly say more about this goal as the President has directed. We are not engaged in a one-time race of "one and done" but a long-term expansion of the American dream. We can argue over relative levels of effort exploring the Moon or Mars or asteroids, but we need both. In order to reap benefits for the American people, we need to bring others with us, pushing technology, and promoting economic development. And not become bogged down at one physical destination or with any one technical concept.

Major Recommendations

Policy Stability: The current U.S. policy is to retire the International Space Station by 2030 and return humans to the Moon before then should be maintained. The geopolitical context and rationale for human space exploration should be clearly understood.

NASA Funding: The NASA budget has been in decline in real dollar terms since the end of the Cold War. If NASA were to have the same buying power today as it did in 1992, its budget would be over $30 billion. In order to justify more resources, NASA needs to innovate more, reduce costs associated with fixed and aging infrastructure, and leverage the private sector to create new capabilities it will want to buy. While ensuring "dissimilar redundancy" for critical capabilities such as lunar landing and crew launch, traditional programs of record should be used only as a last resort.

International Space Station: The station is doing useful scientific work and is being well-utilized, however, its age and increasing number of small anomalies requires continued vigilance to ensure crew safety. It is possible that the ISS may need to end before 2030. This would leave China as the only country with an operational space station. To ensure no gap in U.S. presence in low Earth orbit, NASA is pursuing contracts to spur private development of space platforms on which NASA could be one of several customers. However, NASA has not provided sufficient funds or set clear priorities for these platforms, unlike what it did for the development of commercial crew and cargo capabilities. Efforts to create private LEO platforms should be funded, with efforts to begin transitioning NASA work to them as soon as practicable.

Artemis Program: NASA needs an integrated exploration campaign plan with detailed systems engineering for a simpler, more sustainable architecture. After the decision was made in 2019 to return to the Moon by 2024, NASA was tasked by the National Space Council and Congress to produce such a plan. NASA produced a plan for Artemis missions 1-4, but NASA continues to have difficulty with questions about who will do what, when, and why. An enterprise campaign planning team should be created as part of the Congressionally-mandated Moon-to-Mars program office. This effort can be augmented by NASA Centers and FFRDC/UARC capabilities. The Exploration Campaign Planning Team should be tasked to produce an integrated campaign plan and then periodically updated.

Heavy-lift Space Launch Capability
The United States should seek to use commercial providers for heavy lift capabilities that can sustain multiple crew and cargo missions each year to the Moon. The Space Launch System can be phased out as one or more sources of private heavy-lift are demonstrated.

NASA Infrastructure: NASA is at a crossroads regarding the number and size of facilities it will need in the future as the agency expands its hybrid work environments following the pandemic. Fixed infrastructure costs are a major burden on the agency that competes with funding scientific and exploration missions. Deferring maintenance until equipment fails has resulted in repair and replacement costs up to three times more than had NASA conducted regular maintenance. The NASA Administrator should initiate a streamlining of NASA-wide institutional overhead in the form of workforce and facilities In coordination with the Chief Financial Officer and Human Capital Officer, an intense effort should seek to identify opportunities for a) significant personnel reductions and transfer; and b) consolidation of Center capabilities whose overhead is charged to infrastructure. Saved resources would be reallocated to program offices, with Artemis as the first priority, followed by maintaining a continuous crewed American presence in LEO, science, and aeronautics missions.

Space Nuclear Power: Nuclear power is essential for human and robotic deep space missions. NASA, and commercial nuclear technology developments can benefit each other by lowering risks and costs, thus enabling NASA to acquire necessary power and propulsion capabilities without having to support dedicated and separate technology programs. These private systems need an effective licensing system, yet only two new reactors have been licensed in the United States since 1978. In addition, the Nuclear Regulatory Commission lacks legislative authority to

license commercial nuclear reactors in space. Such legislation was proposed in the Senate in past years but has never made it out of Committee. An existing Presidential Memorandum (August 20, 2019) already addresses the conditions for the launch of spacecraft containing nuclear systems. NASA, DOD, and DOE should propose a pilot acquisition program for space-based uses of nuclear fission reactors.

Humans to Mars: The technologies and practices needed for Mars can and should benefit operations in Low Earth Orbit and at the Moon. Examples include artificial intelligence enabled networks of satellite servicing, repair, and refueling robots with unprecedented levels of precision and accuracy; fully-automated re-entry and landing systems for crew and priority cargo; new families of electric and chemical engines designed to operate only operate in space; inexpensive, radiation hardened electronic components; zero boil-off cryogenic fuel depots; and artificial gravity space stations. All of these can benefit from private sector innovation given the right demand signals from government.

Strategic Choices for the Future

Seemingly separate areas of America's space enterprise – scientific, military, commercial, international, are deeply linked to each other. Large commercial and military constellations are driving high launch rates that are lowering launch prices. Price declines are enabling new space applications and the commercialization of Low Earth Orbit.

Private investments in the expansion of commercial space industries are creating new capabilities that will enable humans to return to the Moon and establish a permanent presence on Mars. The expansion of space activities of all kinds will create new international challenges and opportunities for governance of space and its resources.

In the near-term, the Artemis program is a key element in shaping the geopolitical environment of space. It is not a military program, but it supports national security purposes. The rules of the space environment will be made by those who show up, not by those who stay behind. In the longer term, the expansion of American and allied activity beyond the Earth and into the solar system can be likened to the imperative of building the transcontinental railroad in the 19th century.[1]

When the Pacific Railroad Act was passed in 1862, in the middle of the American Civil War, California had only been a US territory for a little over a decade. Americans loyal to the Union were by no means the majority of the population and no regular troops were present. British forces were stationed in British Columbia, Russian forces in Alaska, French forces in Mexico, and Confederate forces in Tucson were all closer in distance and travel time than any Union regulars.

The project was a high technological risk. No railroad of that length had been built anywhere or had climbed mountains as high as the Rockies. There was no obvious source of useful freight or

[1] This idea is from a forthcoming paper by James C. Bennett.

passengers for the greater part of the distance, except for a few Army forts. Aside from gold and silver, there were no obvious products in California that could provide freight revenues back to the East Coast.

To raise funds, the Pacific Railroad Act provided subsidies in the form of a fixed sum per mile of track laid, and land grants in the form of alternate squares of land, checkerboard style, along the route. The subsidies to the railroad companies provided working capital, and the land grants gave investors the prospect of a large eventual profit. The land along the Pacific Railroad route had almost zero dollar value before the railroad, while most of it gained far more value once it had transportation. The railroad and its shareholders never really got rich from freight tariffs and passenger fares. However, they got very rich from the sale of land grants once the areas became populated, and from all the other economic activity the railroads stimulated.

In the near-term, lunar settlements might be similar to Antarctic research stations. In the longer term, those settlements and those on Mars have the potential to be entirely new communities much as the Great American Desert was transformed by the coming of the railroad. While there are massive technical, economic, and biological uncertainties, the vision of becoming a multi-planetary species is certainly an exciting one. The goal of "Mars" is not just a race but can be thought of as a shorthand term for much bigger, indefinite objectives for America's future.

Mr. Chairman, in closing, I would like to include text from a 2020 report from the National Space Council, "A New Era for Deep Space Exploration and Settlement." The purpose of this document was to describe, much like a congressional report, the context and motivation for the space policy directives approved by the President. To quote:

"The long-term policy of sustainable space exploration and development depends on alignment with enduring national interests such as security, economic growth, scientific advancement, and a stable international environment. As new information comes to light and new experiences are gained, the United States should be prepared to adapt to new opportunities and risks. Although we are not in a Cold War-era space race, space exploration and development are urgent issues. The international environment is dynamic and influenced by competition and threats to the space capabilities on which we rely. Consequently, it is important that U.S. space activities across the civil, commercial, and national security sectors be coordinated at the highest levels and in an integrated manner to advance our holistic interests and those of our international allies. Establishing U.S. capabilities to operate routinely in cis-lunar space and beyond will deliver strategic assets not only for ourselves, but for all like-minded nations who share our values – liberty, democracy, the rule of law, and free market economic principles.

Exploration is fundamental to the American spirit, and space exploration is the modern embodiment of early frontier expeditions. It is the next step in a never-ending quest to explore and develop the unknown, while securing benefits for the American people. Space exploration and development are not confined to one-time missions or any single destination. Rather, the effort described here is one of continually expanding human activity beyond the Earth. Close to home, the United States will encourage commercial activities to lower the public burden of

maintaining and enhancing space capabilities. As the United States journeys into deep space again, it will do so with commercial and international partners as they are willing to participate and capable of participating. At the frontiers of exploration, the United States will continue to lead, as it has always done, in space. If humanity does have a future in space, it should be one in which space is the home of free people."

Thank you for your kind attention. I look forward to your questions.

Biography for Scott Pace

Dr. Scott Pace is the Director of the Space Policy Institute and a Professor of the Practice of International Affairs at George Washington University's Elliott School of International Affairs. In addition, he formerly served as the Director of the International Institute of Science and Technology Policy as well as the Master of Arts program in International Science and Technology Policy. Dr. Pace is also a member of the faculty of the Trachtenberg School of Public Policy and Public Administration. His research interests include civil, commercial, and national security space policy, and the management of technical innovation.

Dr. Pace rejoined the faculty of the Elliott School in January 2021 after serving as Deputy Assistant to the President and Executive Secretary of the National Space Council from 2017-2020. From 2005-2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA. Prior to NASA, Dr. Pace was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy (OSTP). From 1993-2000, Dr. Pace worked for the RAND Corporation's Science and Technology Policy Institute (STPI). From 1990 to 1993, Dr. Pace served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. He received a Bachelor of Science degree in Physics from Harvey Mudd College in 1980; Master's degrees in Aeronautics & Astronautics and Technology & Policy from the Massachusetts Institute of Technology in 1982; and a Doctorate in Policy Analysis from the RAND Graduate School in 1989.

Chairman HARIDOPOLOS. Thank you, Dr. Pace.

I now recognize Mr. Dumbacher for 5 minutes to present his testimony. You're recognized.

TESTIMONY OF MR. DAN DUMBACHER,

ADJUNCT PROFESSOR, PURDUE UNIVERSITY

Mr. DUMBACHER. Thank you, Committee Chairman Babin, Ranking Member Lofgren, Subcommittee Chairman Haridopolos, and Ranking Member Foushee, and all Subcommittee Members for the opportunity to discuss the need for the United States to retain and grow its leadership in space. I refer to my written testimony submitted for this hearing.

I am a proud civil servant to the Constitution, a long-term NASA senior executive in human space exploration, most recently the CEO (Chief Executive Officer) of the American Institute of Aeronautics and Astronautics (AIAA), and currently a Professor of engineering practice at Purdue University. From my experience, I have learned it's about doing the right thing at the right time. Therefore, the discussion is not Moon or Mars. Rather, timing dictates that we must first master the Moon and then proceed to Mars.

I say this because we are at a key crossroads for U.S. leadership in space. Our global competitors, primarily China and its allies, are out-planning and outpacing us in their drive to become dominant in space. This is a critical national security and economic concern. This is about the long-term drive to be present, to lead and become the first to establish the rules of the road, thus mastering the cislunar domain for the purposes of science, exploration, and commercial development. Today's race is about continuous presence, values, and technical leadership. The nation that leads is the nation that benefits.

China is striving to lead the implementation and development of the infrastructure, retaining the high ground, and reaping the economic benefit. China has declared that they will land humans on the Moon before 2030. Of note, China has met every space milestone they have proposed within plus or minus a year.

The United States must protect our potential economic opportunity, protect our national security, lead the building of the necessary infrastructure, and, importantly, lead chartering the rules of the road. We must continue to lead the coalition between the Earth and the Moon, and we must bring international and commercial partners along with us.

NASA's current plan to return people to the Moon requires approximately 35 to 40 starship launches to first demonstrate the capability on an uncrewed mission and then execute the first human mission planned for Artemis III. I ask this: Can 40 launches, development and demonstration of the undeveloped and undemonstrated on-orbit rocket fuel station, and integration of a complex operational scenario across multiple systems all successfully occur by 2030? The probability of success for this plan is remote at best. Further, the United States does not have a sustainable plan for 2030 and beyond. We need to recognize the competitive environment, admit our true technical status and capability, provide the needed effort for success, and engage our international partners.

Private enterprise space capabilities have grown tremendously in the last decade and are driving our progress with government and private investment. We must continue to grow this competitive power. Our workforce across industry, academia, and government—our national asset—must be explicitly supported and grown. Today's workforce is in turmoil when we need them the most. Our strength is tapping into the talent across our society, clearly showing people the opportunity for their own lives. Stability, real, challenging objectives to be accomplished, and real problems to be solved will keep this workforce engaged and learning all to accomplish the future. Unnecessary workforce turmoil allows China additional advantage.

I offer the following recommendations: One, return humans to the Moon as expeditiously as possible by utilizing flight-tested existing systems such as the Space Launch System, Orion spacecraft, and existing international partnerships. This will require extreme focus by the NASA industry Artemis team for the goal of returning to the Moon by 2030, assuring the most efficient and technically rigorous efforts are accomplished.

Recommendation two: In parallel, utilizing the growing private space capabilities, government and academia immediately initiate the planning and implementation of the sustainable and efficient approach to retain the United States' presence on the Moon, assuring our national security and future economic opportunity, consistent with national priorities and policy and the National Academy's decadal surveys.

Three: Focus the NASA industry workforce on accomplishing the national objectives with real timelines and incentives to incorporate new capabilities from across industry, academic labs, and government labs with urgency and focus.

Congress must assure the funding—recommendation four: Congressmen must assure the funding and policy stability, along with the program sustainability, to encourage the best and brightest of our people across our society to lead and implement this critical enterprise for our national security and not economic opportunity.

Thank you for your kind attention and this opportunity to speak. I look forward to your questions.

[The prepared statement of Mr. Dumbacher follows:]

Witness Statement for the Hearing

Step by Step: The Artemis Program and NASA's Path to Human Exploration of the Moon, Mars, and Beyond

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

Rayburn House Office Building
Room 2318

Daniel L. Dumbacher
26 February 2025

Thank you Chairman Haridopolos and Ranking Member Foushee, and all Committee Members for the opportunity to discuss the need for the United States to retain and grow its leadership in space by Mastering the Moon and then on to Mars.

My background: I am a proud former civil servant to the Constitution – a long-term NASA Senior Executive in human space exploration, most recently the CEO of the American Institute of Aeronautics and Astronautics (AIAA), and currently a professor of engineering practice in Aeronautics and Astronautics at Purdue University. During my experience over more than four (4) decades in the profession of space engineering, I have learned it's about doing the right thing at the right time. Therefore, the discussion is not Moon or Mars, rather, timing dictates that we must master the moon and then proceed to Mars.

I say this because we are at a key crossroads for US leadership in space. The challenge facing us is immediate, growing, and extremely capable. Our global competitors, primarily China and its allies, are out planning and outpacing us in their drive to become dominant in space. This is a critical national security and economic concern, as was discussed at the Full Committee Hearing on February 5 – The State of U.S. Science and Technology: Ensuring U.S. Global Leadership, and at a hearing of this Subcommittee in 2016, entitled "Are We Losing the Space Race to China?"

These times are not akin to the space race of the 1960's – "who can get there first." This is the long-term drive to be present, to lead and become the first to establish the "rules of the road" in space position, navigation and tracking, communications, power generation and distribution, resource ownership and allocation – in effect, mastering the cislunar domain for the purposes of science, exploration, and commercial development. Today's race is about continuous presence, values and technical leadership. The nation that leads is the nation that benefits. That nation will establish the norms of behavior which will dictate how sovereign countries will

interact in deep space for decades to come. And that nation, and its citizens, explorers, scientists and investors, will attract powerful partners and allies in accelerating their influence at the Moon - and as a result, on the hearts, minds, and economies back on Earth.

What we know: The Chinese have very deliberately plotted a course, with clear milestone dates, to demonstrate that China is the dominant power in space. Their intent is to catch and surpass the United States by 2030. China strives to be present across all facets of the space enterprise so that they lead the implementation and development of the infrastructure, thereby reaping the economic benefit and retaining the "high ground."

We are in a global competition, every single day.

The Chinese are serious competitors. In 1992 China announced plans to develop human spaceflight capability by 2002, Shenzhou 5 launched with humans in October 2003. In 2011 China announced the Tiangong space station would be assembled from 2020-2022, modules were launched in 2021, and two in 2022. Robotically China has returned samples from the far side of the moon in 2024 - no other nation has accomplished this feat. They plan to arrive at the south pole of the moon in both 2026 and 2028.

The key takeaway is China does what it says it's going to do, +/- a year. This is all part of the published China Space Strategy[i]. China plans to land humans on the moon "before 2030", leading to a permanent lunar base by the mid-2030's. China's aim is to be the dominant leader by being present and establishing the critical infrastructure. China publicly is developing the partnerships, even with our allies, to achieve their goals.

China is not the only nation working on furthering its ambitions in space. Russia is now partnering with China[ii]. China is building partnerships with nations, including some of our allies, to develop requisite capabilities. For example, Chang'e - 6 included instruments from France, Italy and ESA. It is absolutely critical that the United States reinforce existing international partnerships and build new partnerships. We have weakened our US / International partnerships in the past by dramatically changing our plans. We must be seen as reliable for the long-term leadership in space. The International Space Station and the James Webb Space Telescope serve as very successful models for building on our international commitments.

The large number of commercial, national security satellites and assets between earth and the moon, and the capabilities that will be installed on the moon over time, will provide space faring nations with the capability to access, capture and/or destroy assets between the earth and the moon. This is the proverbial "high ground." Additionally, resources on the Moon such as water ice, helium 3 and possible rare earth elements, will be critical to our lunar presence, our ability to expand to Mars, and even to life on earth.

Retaining U.S. leadership in space demands that we be actively present from the earth to the moon for the foreseeable future. This establishes our credibility and credentials. The United States must protect potential economic opportunity, protect our National Security, lead the

building of the necessary infrastructure, and importantly lead chartering the "rules of the road." We must continue to lead the coalition from the earth to the moon, and we must bring international and commercial partners along with us. The Artemis Accords are a key step in establishing these critical partnerships. We can then proceed to Mars when the time is right.

Where is the United States?

The United States (NASA) last put people on the moon in 1972. We have mapped the moon since 2009, and attempted commercial, cargo landings on the moon in 2024, with additional cargo landings coming in 2025. We have test flown our spacecraft and rockets around the moon in 2022, with our international partners, the European Space Agency.

The United States approach to space exploration has evolved over time. In the mid-2000's The Vision for Space Exploration set a course eventually manifested in NASA's Constellation Program to return to the moon and then go to Mars. In the 2009-2011 timeframe, the Constellation Program was cancelled and NASA adjusted, resulting in establishment of the Space Launch System and the Orion spacecraft. The Artemis Program was established in 2017, with the Human Lander System announced in 2021. Throughout this history, NASA has been working per NASA Authorization Acts of 2008, 2010, 2017, and 2022 to return to the moon and then take humans to Mars.

Today, I admit, however, that the current plan to return people to the moon is very suspect. The Aerospace Safety Advisory Panel (ASAP) in their recent 2024 report[iii], described NASA's Artemis 3 first human flight as high risk, "...aggregated risk associated with accomplishing so many "first-time" milestones, including several critical prerequisite demonstrations, may be too high."

The ASAP assessment highlights 14 critical "first-time" milestones, including the development of the poorly understood and under-researched cryogenic rocket fuel storage and transfer technology. By NASA's own plan, approximately 40 large Starship Launches are necessary to first demonstrate the capability on an uncrewed mission, and then execute the first human mission currently planned for Artemis 3. The question becomes: Can 40 launches, development and demonstration of the undeveloped and undemonstrated on-orbit rocket fuel station, and integration of a complex operational scenario across multiple systems, all successfully occur by 2030? Any objective assessment, including my own view, concludes that our approach today has a very low probability to match the "before 2030" milestone for landing humans on the moon. In other words, the probability of the United States safely landing humans on the moon by 2030, with the current plan, is remote at best.

Further, the United States does not have a sustainable plan for 2030 **and** beyond. We need to recognize the competitive environment, admit our true technical status and capability, provide the needed effort for success, and engage our international partners. This includes the European Space Agency, the Japanese Space Agency (JAXA), the Canadian Space Agency (CSA), and others. NASA currently has a process for addressing objectives, but no timeline, no sense of

needed resources. To be a great nation that leads in space, we need a flexible, sustainable approach, adjusting as we learn. This is the definition of "exploration". We must adjust as new capabilities and technologies come to fruition, and achieve our national objectives on the necessary timeline. We can take advantage of the on-going efforts on the Human Lander Systems, lunar systems, and technology development and build these into the sustainable program we need to retain our leadership in space.

From a technical and human point of view, going to Mars is orders of magnitude more difficult than returning to the moon, 36 million miles versus 240,000. Furthering the technology, developing the systems and demonstrating at scale the needed capabilities, along with how humans live and work in the microgravity and radiation environments and the long-term psychological impacts, continue to be open questions. While Congress has repeatedly endorsed Mars as an eventual destination, it has also recognized in law for almost 20 years the importance of a consistent space policy that captures both the nearer-term scientific, international and commercial value of returning to the moon on a permanent basis while continuing development toward Mars. The bipartisan and bicameral agreement on continuity of purpose thus underpins our national effort to date and spurs it forward.

At the same time, we cannot continue to do "business as usual". Dr. Griffin stated it very well in his testimony of January 17, 2024 to this Subcommittee[iv]. "The Artemis Program should not be "kept on track"; it should be fixed and then prosecuted with all deliberate speed." Dr. Griffin's suggested "lower risk" approach is precisely what we need to be doing, with all deliberate speed.

Current Realities

Private enterprise space capabilities, driving today's innovation and progress, have grown tremendously in the last decade. Over the past 10 years, nearly 700 start-up companies focused on space and satellite applications/markets have raised over $66B (~200 start-up companies raised $8.2B in 2024). We have reached the time where the United States private enterprise competitiveness and innovation is driving our progress with government and private investment. We must continue to grow this competitive power. This is how a sustainable future is built. Initially, government investment moved us through the early challenges. Today's combination of private investment and government support provides the United States with unmatched capability. Our efforts on human landers, commercial cargo landers, lunar space suits, lunar surface systems and associated technology provide a starting point. We must utilize, foster and grow this capability, it is our super power along with our people.

The United States has made investments, and the results are clear. For example, the current growth and efficiencies in launch systems, particularly the return and landing of rocket stages, is partially attributable to NASA investments in the mid-1990's and early 2000's. Air Force and NASA investments in vertical landing and launch system technologies have supported the reduction of the cost of access to space. These investments provided the initial technical capabilities and skilled workforce that has now grown to the capabilities of SpaceX, Blue Origin,

and others. These investments by the United States taxpayer, are key stepping stones to the observed success of today.

Our workforce, across industry, government and academia, will make our dreams real. We must explicitly support and grow our national asset, our workforce. We must nurture and grow our people. Stability, real objectives to be accomplished, and real problems to be solved will keep this workforce engaged and learning, all to accomplish the future. These people will be inventing the technologies, applying existing capabilities in new ways, creating the technology for future markets, and building the future marketplace. Our strength is tapping into the talent across our society, clearly showing people the opportunity for their own lives.

For example, the United States Hispanic population is 19% of the total population. According to the American Society of Engineering Education (ASEE) 10.7% of our engineering graduates are Hispanic. Similar examples exist for other groups in our society. The Honorable Heather Wilson, in the full Committee Hearing of February 5, 2025 made a similar point. We must include all of our talented people that want to be part of this enterprise, and help the United States in the global competition. Estimates show that the US annually graduates 10-20%[vvi] of the number of engineers that China graduates. We need everyone, from all backgrounds.

Why Does it Matter?

Human progress and economic opportunity are born out of curiosity, exploration and ultimately utilization of new technologies within new markets. The growth of the United States from 13 colonies to ultimately 50 states is one example.

Expansion to the west in the 1800's developed the economic infrastructure, railroads, supply chain and economic opportunity of the United States to the point where today, one state - California, is the fifth largest gross domestic product in the world - comparable to all of India.

Similarly, being present and developing the necessary infrastructure between the earth and the moon to build and grow the economic opportunity for both today and future generations is at the heart of the United States value system. The United States must lead so that our principles and values drive the benefit for the United States citizens and all the global citizens.

In today's world, our future as the global leader depends on being seen as a leader in space. Being present at the moon, building the infrastructure from the earth to the moon, importantly results in economic opportunity and growth for our citizens. We must also recognize that economic security is protected via our own national security.

Therefore, our continuous engagement in space exploration, space utilization, and our national security in space is essential for the protection and growth for our citizens.

Recommendations

Assuming the United States wants to retain its leadership in space, the following recommendations are provided:

1. Return humans to the moon as expeditiously as possible by utilizing existing systems such as the Space Launch System, Orion spacecraft, ground systems and existing international partnerships. This will require extreme focus by the NASA / industry Artemis team for the goal of returning to the moon by 2030, assuring the most efficient and technically rigorous efforts are accomplished;
2. In parallel, utilizing the growing private space capabilities, government and academia, immediately initiate the architecting and implementation of the **sustainable** and **efficient** approach to retain the United States presence on the moon, assuring our National Security and future economic opportunity, consistent with National priorities and policy, and the science priorities from the National Academies Decadal Surveys;
3. Focus the NASA / industry workforce on accomplishing the national objectives, with real timelines, and incentives to incorporate new capabilities from across industry, academic labs and government labs;
4. Congress must assure the policy and funding stability along with the program sustainability, to encourage the best and brightest of our people, across our society, to lead and implement this critical enterprise, for our national security and economic opportunity.

Summary

In summary, our Nation, faces a very clear question. Do we want China to be the dominant space nation, or do we, the United States, want to retain and expand the leadership we have built across decades through investment and sacrifice?

From my perspective, the United States must be present, retain the lunar high ground, remain the key leaders in the development of the space economy for our citizens and future generations. We must not allow our global competition to have the high ground and the benefits.

To achieve the near-term milestones, we should use the existing capabilities that have successfully been flight tested for the lunar mission, the Space Launch System, Orion and the Exploration Ground Systems. AND, we must do it with much greater urgency than we have today.

In parallel, we must develop the long-term, sustainable approach for the United States to retain its leadership in space, establish the "rules of the road," and build the infrastructure for the economic benefit of the US citizens.

Congress must put forward the policy and the appropriations to master the Moon. The United States can extend humans to Mars when it makes sense.

Thank you Chairman Haridopolos and Ranking Member Foushee for the opportunity to discuss this critical issue facing our Country. I look forward to your questions.

---

[i] Baturin, M. (2024, October 23). *China space plan highlights commitment to space exploration, analysts say*. Voice of America News. Retrieved February 20, 2025, from China space plan highlights commitment to space exploration, analysts say, https://www.voanews.com/a/china-space-plan-highlights-commitment-to-space-exploration-analysts-say/7836873.html

[ii] https://www.newsweek.com/russia-approves-plan-establish-lunar-base-china-1848731

[iii] Aerospace Safety Advisory Panel 2024 Report, https://www.nasa.gov/asap-reports/

[iv] https://republicans-science.house.gov/_cache/files/2/d/2dc97bb6-040b-4d15-ae69-6b8de637174d/448A0B95841995613C9A9B19135C104C.2024-01-17-griffin---testimony.pdf

[v] https://ira.asee.org/wp-content/uploads/2024/12/Engineering-Engineering-Technology-By-the-Numbers-2023-1-combined.pdf

[vi] https://www.linkedin.com/pulse/chinas-engineering-capabilities-workforce-2024-munkholm-%E5%AD%9F%E5%8F%AF%E5%92%8C-fxrnf/

Dan Dumbacher is a Professor of Engineering Practice at Purdue University, formerly the Chief Executive Officer of the American Institute of Aeronautics and Astronautics (AIAA).

Dan has served in senior executive roles at NASA, including the Deputy Associate Administrator, Exploration Systems Development Division, Human Exploration and Operations Mission Directorate at NASA Headquarters. Dan's roles have included groundbreaking flight test of the initial vertical landing rocket, DC-X/XA, development of technologies to reduce the cost of access to space, NASA development of the X-37 flight vehicle prior to transition to the U.S. Air Force, and as Engineering Director at the NASA Marshall Space Flight Center in Huntsville, AL.

During his career, he has received numerous awards and honors including the coveted Silver Snoopy Award and the NASA Distinguished Service Medal. In 2015, Purdue recognized him with the Gustafson Teaching Award. Dan has also been named as a 2025 Distinguished Engineering Alum by Purdue University.

Dumbacher earned his bachelor's degree in mechanical engineering from Purdue University and a master's degree in business administration from the University of Alabama in Huntsville. He has also completed the Senior Managers in Government program at Harvard University.

Chairman HARIDOPOLOS. Thank you to both witnesses for testifying today. I now reserve for myself 5 minutes for questions.

My first question is, each Artemis mission is a complex web of interdependent systems. I would ask Dr. Pace first. In your view, would any changes to the current Artemis mission architecture get us there faster, or are there more likely to be delays in our return to the Moon?

Dr. PACE. OK. Thank you. That's a great question. One of the things I said my testimony is I think we need to have sort of a more immediate campaign plan. The architecture itself—I think the idea of using public-private partnerships for going to low-Earth orbit, landing on the Moon, all of that, I think that is basically fine. The policy direction is fine. Where I was particularly pointing at is a need for a more sustainable, more reusable systems for going from the Earth to the Moon, which is why I talked about having an on-ramp, if you will, for alternative heavy lift options.

The Artemis II and three cores are already under construction, being built. I wouldn't propose really changing that. I think trying to change that and do something else would produce more delays and would push us past 2030. But as I look beyond that, the next II and III—Artemis II and III missions, maybe IV, we should be thinking about other alternatives we can have to have that sustainable presence. So the first is, can we get back to the Moon, you know, faster? Tons of things to do to work on that, as Dr. Dumbacher says, and then the question is, be able to sustain that and be there over time. That's going to require, I think, changes in what we do and bringing on new capabilities that we do not currently have.

Chairman HARIDOPOLOS. Thank you, Dr. Pace. And, Mr. Dumbacher, a second question. As the Committee has noted, NASA's faced a lot of challenges with Artemis. What lessons could we learn from our private partners who've had so much success over the last few years?

Mr. DUMBACHER. One of the lessons we can learn that would be most beneficial would be applying the rapid urgency and focus that we see from our private companies, the ability to solve and rectify problems in a very timely manner, decision velocity being much increased so that it doesn't take—we get decisions in short weeks and not months, which all goes to cost and all goes to affordability.

The other changes I would propose is that—similar to Dr. Pace is let's use the—as I say it, the tools in the toolbox we already have, the hardware online with Artemis, and we might have to build a lander. We might have to scale down the current lander opportunities, examples that we have in work so that we get to that 2030 landing. But most importantly is get the decision velocity dramatically increased and get the efficiency and the urgency and focus clear all throughout the program.

Chairman HARIDOPOLOS. My next question is, how can the United States continue to leverage commercial partnerships to outpace international rivals in lunar exploration and beyond, Dr. Pace?

Dr. PACE. I think that's really one of the key things. In Space Policy Directive 1, the President put in commercial and international partnerships because it represents a very different way of

doing business today than it did during the Apollo program. So we need our international partners to shape the environment. We need commercial partners to actually provide the innovation necessary to—in an affordable and sustainable way make progress toward the Moon and Mars.

I think the partnership there is not just simply one of money going back and forth and who builds what, but also in terms of just cutting down the kind of regulatory oversight that doesn't really always add value. You have small companies around the United States who be happy to build a couple of hydrogen valves for us, but really don't because the paperwork is just ridiculous, and they just really can't do it.

There are a lot of reforms that the DOD (Department of Defense) is looking at in terms of acquisition. Those similar kind of reforms are ones that NASA looks at in acquisition because what we need to do is shape an industrial base that provides the capability for the United States to explore and go where it wants, when it wants. And one of the things really standing in the way is ourselves, the way we do business. The old styles that we did business that worked, I think, during Apollo, Shuttle, and even Station are not ones that really work today. We need more commercial companies willing to work with the government and provide things to the government. In many cases, they're not because of the burden that regulatory processes that we require impose on them. So we obviously need to have better transparency. It's not just buy and trust, but we need to find ways that reform the way we integrate and work with the private sector to get them to want to be part of us.

Chairman HARIDOPOLOS. Thank you, Dr. Pace. And let me ask a point-blank question to Mr. Dumbacher. You mentioned a lot of these concerns. If Artemis doesn't work in 2026 as we all hope it will, what would you recommend we do?

Mr. DUMBACHER. First of all, I'm confident that Artemis II will work, knowing the technical workforce that's behind it and making it happen. It's a matter of doing it quicker and getting to Artemis III quicker. I think right now our problem is, is because of our lander designs and other opportunities, we have developed this complex, multiple-launch scenario that keeps us from getting humans to the Moon by 2030. And so what we need to fix is how we execute Artemis III and get Artemis II flying as quickly as possible.

Chairman HARIDOPOLOS. Thank you very much.

And with that, I now recognize our Ranking Member from North Carolina for 5 minutes for questions. You're recognized.

Mrs. FOUSHEE. Thank you, Mr. Chairman. I am proud that North Carolina-raised Christina Koch has been named to the Artemis II crew and will be the first woman to travel beyond low-Earth orbit. I am appalled that the Trump Administration's attack on any effort to even acknowledge the underrepresentation of women and people of color in STEM (science, technology, engineering, and mathematics) fields, let alone addresses the issue.

Mr. Dumbacher, why is it so important that our astronaut corps is representative of our Nation and that NASA engages all Americans of every background in its mission?

Mr. DUMBACHER. Congresswoman Foushee, the—one of the things I learned very directly as the CEO of the American Institute

of Aeronautics and Astronautics and also one of the reasons I went back into teaching is because it's about people need to see themselves, and they need to see the opportunity. They need to know that people like them can accomplish and execute, and they—the more they see of that, the better it is. And it also is critical that those people and their support networks, their family, their friends, their relatives, also see that opportunity. So being representative of society, as the AIAA worked to do over the course of our strategic planning, is absolutely critical so that all of our Members of our society are engaged and included in what we do.

Mrs. FOUSHEE. So a follow up to that is, how will actions that turn away talent and discourage the next generation affect NASA's efforts to return humans to the Moon and land the first astronauts on the surface of Mars? Many of the probationary employees who are being considered for layoffs are just getting started in their careers.

Mr. DUMBACHER. It is a—very much a concern, and in fact, over the weekend, I had the chance to talk with former students, NASA employees, that are scared. They are concerned because of the turmoil. And believe me, they are some of the smartest people. I am more than happy to turn over the future to them. And they are concerned, and they see that, and they are actually questioning, what are they going to do for their careers and looking at other opportunities, which I think is terribly sad because of the national imperative that we have and the global competition that we are engaged in. As Dr. Pace has alluded—has discussed and I have discussed, we are in a global competition, and if we don't take advantage of all of the talent across the society, across the United States, then we do that at—we give up that capability at our peril.

Mrs. FOUSHEE. Thank you for that acknowledgement.

Dr. Pace, in your written statement, you note that space leadership is about having other countries wanting to work with you to be a partner in common endeavors. I share your sentiment. However, recently, Mr. Musk abruptly asserted that the International Space Station, a beacon of international space cooperation between multiple nations, end operations 3 years earlier than planned so that we can go to Mars. Are you concerned about the impact of this type of comment, what it might have on our ISS partners, many of whom are also involved in Artemis?

Dr. PACE. So I saw the comment, and interesting. I guess I would say, first of all, that it's not really fully accurate in the sense that we've gotten all the value we can out of Station. There's lots more value still to be had of doing research and work on board. Just as one example, the environmental life support system aboard Space Station is mostly closed. Over 90 percent of air and water is being recycled. They can do that for up to 3 years. That's important for going to Mars, and so being able to demonstrate life support systems for that.

On the other hand, I would say that that Mr. Musk has a point about being prepared to deorbit. We have problems aboard the Russian segment of the module. We have an air leak. I was woken up at 6:30 in the morning in 2019 to be told that there was, you know, an air leak and that we needed to pay attention to it, and we start-

ed worrying about crew safety. So this has been going on for a while.

I have concerns about whether or not the station will, in fact, be safe and habitable. It is now, but whether that be through to 2030. So I think it's wise to be prepared to come down sooner. I just don't think it's because there's not more to do. There's plenty to do. But we do need to be prepared to come down sooner if need be for safety reasons.

Mrs. FOUSHEE. Thank you for that. A final comment, I have said before that the safety of NASA's astronauts is always top of mind for me and for everyone involved in overseeing our Nation's space program. NASA is increasingly turning to commercial services—commercial service models, rather, for human space flight. I believe it is critical for the agency to have well-crafted and targeted oversight procedures that can ensure its contractors are every bit as committed to a culture of safety as NASA itself.

I wish that NASA had agreed to testify here today so that I could ask them directly, but I would like to still hear from you, Mr. Dumbacher, as you have had a long career in human space flight programs at NASA. How do you see NASA's ability to evaluate and ensure that human spaceflight contractors maintain a robust safety culture commensurate with the risks of deep space exploration and extremely high stakes, the lives of our astronauts?

Chairman HARIDOPOLOS. And if you could please keep it brief. Yes, thank you.

Mr. DUMBACHER. Certainly, astronaut safety is key. I wear today my silver Snoopy pin to recognize that. It is—it's about appropriate oversight and insight, not overbearing, and getting to that right balance is the key. And we have drifted to overbearing, very risk-averse, and we need to back—we need to rebalance so that we get more—the proper insight at the proper risk and be able to move on with decision velocity quickly.

Mrs. FOUSHEE. Thank you. And I yield back, Mr. Chair.

Chairman HARIDOPOLOS. Thank you. And I recognize the Representative from Florida, Congressman Webster, for 5 minutes.

Mr. WEBSTER. Thank you, Chairman. Thank you for having this hearing, and it sounds like it's very important to be done right now.

And, Dr. Pace, you mentioned that the Artemis program needed revision, and you later said, maybe it doesn't need that much revision. What do you—what does that entail?

Dr. PACE. I think the—one of the primary things it entails is, what do we do after Artemis II and III? I think the Artemis II mission is underway and keep going. Artemis—the other missions for landing, I think, to beat their—beat the Chinese back I think are fine. But I think, looking beyond that how do I make sure we're able to go back and forth to the Moon in a sustainable way and buildup the capabilities necessary, really, to go to Mars?

So I would say the immediate campaign plan, if you will, for the next several missions is going to be important to get there ahead of the Chinese, and then we need to be able to think and how are we going to stay there in a way that's sustainable and affordable? So, as I said, I think the policy direction is fine. I think the major elements are fine. We need alternatives for heavy lift in the case

of the SLS because it simply hasn't been able to produce enough of them, which the Congress has directed it to do, to provide more opportunities.

And other than that, it's we got to go fly. We got to go get experience. And if we just simply sit on the ground, we'll have a lot of hangar queens, but we won't really get the data that we need. So I think the program is at the point where it really is about to fly. It needs to fly more, and I'd like to see us get that experience.

Mr. WEBSTER. So would you say that this would be a high priority for the new NASA Administrator?

Dr. PACE. I think probably the—I would suggest that his—one of his highest priorities is to really get a group of people together and in fairly short order, not a yearlong study, not another, you know, large effort, but to say, OK, what are we really going to do to meet the directions that the Congress and the White House have given to us? And if I may be so bold, I think you could come up with an answer in about 60 days or less, so—people have all the reports necessary, and the data analysis is all sitting on the shelf now. It's a matter of that decision velocity, as Dr. Dumbacher said, to pull a lot of that stuff together and to really report back to you and the White House as to what needs to happen in the President's budget request, what needs to happen in the authorization bill. And if we're—unfortunately suffer under a continuing resolution, what things to prioritize in that environment, so—because you all have some really important decisions to make.

Mr. WEBSTER. Well, you've kind of answered that. The next question would be, what process would there be for revising the Artemis program? So that would be the idea of making haste, making it happen, making it fast. Is that correct?

Dr. PACE. Yes, because if we want to go to Mars, we have to learn a lot of things that are necessary for going to the Moon. The step-by-step approach, the incremental approach that this Committee has talked about and really this Congress has supported since 2005 represents, I think, a bipartisan consensus that is correct. We have to do a lot of work. There's no shortcut. There's no easy way to learn how to live and work and operate in space and get to Mars. So we have to do the work. And the sooner we do the work, the sooner, you know, we're going to get there.

Mr. WEBSTER. OK. Well, I think you're right. Get to work. Thank you so much for your time. I yield back.

Chairman HARIDOPOLOS. Thank you, Representative Webster.

Next, we recognize the Congresswoman from California. Congresswoman Lofgren, you're recognized for 5 minutes.

Ms. LOFGREN. Thank you very much, and thanks to the witnesses for this thoughtful testimony.

I am concerned about the impacts of the chaos of recent weeks on our NASA workforce. For example, I think that the 20-something hackers may not realize that when you get a merit-based promotion, you are put on probationary status for the merit-based new job. Those are the people targeted for layoffs, the people who are most meritorious. I mean, this is chaos.

The NASA acting Administrator said at a commercial space conference recently that NASA is focused on implementing the Executive orders. Instead, I think that NASA's workforce needs to be fo-

cused on getting the NASA mission done. I see this first-hand from my constituents who work at Ames Research Center, which is outside my district, of course. But the chaos, the confusion, the whiplash, intimidation, and bullying of the workforce is agency- and governmentwide. And every day, NASA employees are worried that they or their colleagues are going to be arbitrarily fired, or they're reportedly getting told to hide pride stickers in their cubicles. They don't even know if the Administration is going to tell them to abandon the Moon altogether.

And when it comes to Artemis, I'm also concerned about the unprecedented influence Elon Musk seems to have on strategic direction in this Administration. Ranking Members Foushee, Sykes, and I have sent letters questioning NASA on so-called DOGE (Department of Government Efficiency) and the potential conflicts of its leadership at NASA. And even though SpaceX has contracts worth billions for developing human landing systems for the return of our astronauts to the Moon, Mr. Musk keeps talking about heading straight to Mars. Beyond the obvious fact that this approach is—could serve his personal interest, I think it's bad policy.

And I'd like to ask both of you, Mr. Dumbacher and Dr. Pace, you're both experts, so please, in your opinions, why are we going to the Moon while keeping our sights on Mars, and what would it mean to abruptly change the longstanding Moon-to-Mars approach?

Mr. DUMBACHER. I will take it first and then turn it over to Dr. Pace. I think why we are going to the Moon is to, as Scott has said, learn. It's also about making sure we are there and present for the long term to help establish the rules of the road, reap the economic benefits, and help retain the high ground. This is an important—we need to learn along the way, and we need to recognize that the global competition is occurring from the Earth to the Moon and to the lunar surface. There is not a global competition yet for Mars, so we need to take right—the right thing at the right time, Moon first, then Mars.

Dr. PACE. Thank you very much for that question. I would say—well, first of all, you know, leadership in space today is different than Apollo. Apollo is about, look what we can do by ourselves. Today, it's about, look what we do that gets——

Ms. LOFGREN. Right.

Dr. PACE [continuing]. Other people to want to be with us. I would also submit that the idea of going directly to Mars actually was already tried. It was tried during the Obama Administration when they abandoned the Moon and said, well, let's go to Mars. Of course, I was very critical of this, not because I was critical of Mars, but because I was critical of a program that I thought was disconnected from geopolitical reality. Other countries really couldn't cooperate with us.

And so when SPD–1 was—after it was signed, I had the opportunity to be in Tokyo at a major space meeting, and the tenor of the room was completely different. People were like, oh, we can do the Moon. What do you need? How can we help? What can we be part of? Yes, they're with us on the idea of Mars as the goal and build forward to that. But to do that separate from where other people are, I think, left the United States in a worse geopolitical

position, not intentional, but it left us in a worse position as a result.

So I think while people can have their personal interests in how to go about space exploration, I think the national interest is one which really enhances the position of the United States, and the sequential steps that the Congress has laid out are, in fact, in those national interests.

Ms. LOFGREN. So we need to put our national interest ahead of our personal interests. And I appreciate your insight. And I hope that our Committee will maintain its bipartisan effort to support the plan that is workable in the national interest, is likely to beat our major competitor China, and not go off on wild tangents that appear not to be well thought out.

With that, Mr. Chairman, I yield back.

Chairman HARIDOPOLOS. Thank you. I now recognize the Representative from Georgia, Mr. McCormick, for his 5 minutes of questions.

Mr. MCCORMICK. Thank you, Mr. Chair, and congratulations on your new position.

Chairman HARIDOPOLOS. Thank you.

Mr. MCCORMICK. I am really excited to be here today and talk to you folks about what works. We are in increasingly difficult times when it comes to global competition. And even countries who are not traditionally known for space travel have done very well with India putting an aircraft on the far side of the Moon for under $100 million. I don't think we could get an organization together to talk about making a spaceship for under $100 million. I mean, that's just the reality of it. We can't get through the administrative process for that much money, let alone actually put metal together and put rocket fuel in something and actually get the technology to work.

We're not efficient at all. I think we'd all agree on that. And that's one of the reasons that we're falling behind China. You mentioned today about how we're falling behind China, because they meet their marks. When they set a goal, they actually get there because, of course, they have a unified government, because one person kind of calls the shots, and I get the efficiencies of that.

But what I'm looking for is solutions because, right now, this doesn't affect just getting to the Moon or getting to Mars. This is the way we face intelligence in armed services. We're talking about EMPs (electromagnetic pulses). We're talking about space weapons. We're talking about the ability to defend ourselves and be on the offense when it's necessary to take out something that's going to harm American citizens. This is about everything that we hold near and dear. It's not just one thing.

My question is, in a time where we're continuing to advance rapidly in the commercial industry but we're falling way behind in every government contract we do, why isn't—why aren't we turning to more outside-the-box thinking when it comes to collaboration, when it comes to—when we can see one program is obviously failing, and then you got one man who's putting more spaceships into outer space than all other nations combined and actually bails NASA out when we leave somebody stranded. Why aren't we doing better collaboration? And what can we do better specifically? And

I'll give you the first crack, Dr. Pace. I love your comment, by the way, on the hangar queen. As an aviator, that's near and dear to my heart. Hangar queens come from inefficiencies. When we have parts problems or people problems, we get hangar queens. That's what we have right now. I couldn't agree with you more.

Dr. PACE. Well, thank you. I think one of the things we need to do and one of the ways to—going back to inspiring the workforce and to keep them sort of focused is to give them real and tangible things to go do. When you do flight test, when you do hardware, it kind of drives out nonsense. It doesn't clog up the system when you're actually sort of working and flying. And we put a lot of nonsense in the way of people getting their jobs done.

And so the reason why we have acquisition issues is because we often prioritize our bureaucratic processes over and above the mission. The mission becomes secondary to making sure the paperwork is filled out directly. You'll have tons and tons of specification documents, disclosures and so forth on, you know, cost-plus contracts. All of it's there and required. It's been built in. But you really ask, is this really adding value?

I think one of the things that I would worry about both on the NASA side and on the DOD side is that we're not able to take advantage of the innovation that's there and potentially available for us in the private sector because people really won't want to work with us. You look at the number of companies that sell to the commercial sector, versus selling almost exclusively to DOD, in the past, during—you know, back in the 1990's—prior to the 1990's, companies would sell to both government and industry. Today, there's an increasing number of the larger companies that sell really only to the government, and so there's been kind of a separation in the U.S. industrial base in the economy. We need to sort of take down those barriers to where private companies are more willing to partner and work with the United States so we can get that innovation that we need.

Mr. MCCORMICK. And you would agree that the private sector is vastly outpacing our capabilities in the government sector?

Dr. PACE. I would say there are some tremendous capabilities in the government sector that don't exist in the private sector, OK, but the innovation that the private sector is able to do is because they don't have the other burdens that government carries with it. So there are really some smart, capable——

Mr. MCCORMICK. You're talking about regulation. I couldn't agree with you more.

Dr. PACE. Regulatory relief and acquisition streamlining is probably one of the most important things common to both defense and NASA's——

Mr. MCCORMICK. And that's been holding us back, both in private and government space exploration?

Dr. PACE. In a world that is much more innovative and moving much faster than it ever did before.

Mr. MCCORMICK. I got about 30 seconds for you to wrap us up, sir.

Dr. DUMBACHER. Well, I think to pull a thread a little bit further, I think, actually, if you give the leadership and the team at NASA and in government a little bit more leeway to go do their job, they

will go do it. I have seen first-hand examples inside the agency, and I lived it myself where, given the right leeway, given the right motivation, and given the right resources, we went off and accomplished things—vertical landing before it became commercial—can actually be done in the government and can be done quickly if given the right leeway.

Mr. MCCORMICK. I couldn't agree—and just a summary point, Mr. Chair, is that basically when people who are doing the hard work are left alone—because they want to be safe. I want to survive my mission. If we're left alone to actually accomplish our missions, we'll be the safest people alive. But if you overregulate us, you overburden us, we will fall behind, and this is a global competition.

Thank you so much, gentlemen. And thank you, Mr. Chair.

Chairman HARIDOPOLOS. Thank you. And with that, I recognize the Representative from California, Mr. Whitesides, for his 5 minutes of questions. Welcome.

Mr. WHITESIDES. Thank you, Mr. Chairman. I look forward to working with you, as well as Ranking Member Foushee. It's so good to be here for this first meeting. I also want to say I'm looking forward to working with Ranking Member Lofgren and Chair Babin.

I also want to call out somebody who's been to space here in this hearing, which is Pam Melroy, former astronaut and Deputy Administrator. We're thankful for your service for the Nation and for all you've done, so thank you, Pam.

I want to recognize the witnesses. I think, Dan, your leadership in engineering and your work at AIAA is super important for the Nation. And, Scott, I think your tenure as Executive Secretary was one of the best-run periods of space policy, and so I want to recognize you both.

I want to start by sending a message to the NASA employees out there, which is that we hear you, we support you. As you said, Dan, people are scared. And I think we as a Committee have a strong interest in a workforce that is supported, that feels able to conduct its mission, and that is not running scared. And so I know that I have been getting many messages from folks who feel under attack. They don't know if they're going to get fired after we have a confirmation of the next Administrator. This is not the situation that is conducive to expanding our leadership in human spaceflight. And so to those folks, I want to say we're going to do everything we can to support you, and we are going to do everything we can to build an agency that that continues to do great things.

I'm particularly concerned for the NASA centers in my area, NASA Armstrong and JPL (Jet Propulsion Laboratory). We've had various folks who are already affected by the different employee actions that the Administration has pursued. And of course, we're very concerned about the specter of probationary firings. So let's start there.

Dan, you talked about this a bit in your testimony. Now, probationary employees are sometimes people who have been promoted, but often they are the younger generation. How important is the

next generation to pursuing an ambitious space exploration program?

Mr. DUMBACHER. The next generation is absolutely critical because they need to replace old guys like me. They—that's going to be the long-term talent, and it takes time to build the talent. We are talking about dealing and addressing the challenges that human beings have not addressed until this generation. The combination of the private enterprise power capability, the combination of the government and academic communities is critical, and the young people are our future. And getting them and bringing along young people throughout our society to tap into those—to tap into that talent we haven't tapped into in the past is absolutely essential for this global competition we're in.

Mr. WHITESIDES. Thanks a lot. All right. So next question—and I think this is potentially an issue where we can keep returning to—is the issue of risk. And, you know, if we are to compete with the Chinese, which we absolutely need to, and if we are to just do anything because we've been trying to go beyond low-Earth orbit for over 50 years with humans, I think we need to look at our Nation's risk posture, and that is going to be a national conversation that we need to have.

There's the old phrase that failure is not an option, and I think that that has been toxic to America's space program because the reality is that if you're trying to do hard things, you're going to fail sometimes. And of course, we want to make sure that everyone is safe on board, and we need to make sure that we are—we're pursuing a structure that enables us to take smart risk.

And so I was wondering, Scott, if you might want to talk to that, or Dan. You both have a lot of experience in it.

Mr. DUMBACHER. Well, let me start since Scott let me. I look at the statement as failure is not an option when I have people on board. Failure is an option when I'm on the test day and trying to understand the limits and I'm trying to figure out where fail—where those limits are so that I can protect the people that are onboard that launch vehicle or in that spacecraft.

I think risk, we have become more risk averse over time. Our workforce has essentially been—on the human spaceflight side has been hired since Challenger and Columbia where failure is not an option has been the mantra. Science community has an ability to learn how to go through these programs in the full life cycle. We do—we have not had that opportunity as much on the human spaceflight side, and our workforce needs to have those opportunities and those flight tests and flying hardware like Scott alluded to earlier so that we can get that experience and get that capability rebuilt.

Mr. WHITESIDES. Thanks. I yield back, Mr. Chairman.

Chairman HARIDOPOLOS. Thank you very much. I now recognize our Chairman from Texas, Dr. Babin, for his 5 minutes. You're recognized, Mr. Chairman.

Chairman BABIN. Thank you, Mr. Chairman.

And, Dr. Pace, Congress directed NASA to establish the Moon to Mars Program Office as part of the last *NASA Authorization Act* signed into law. The Aerospace Safety Advisory Panel's, ASAP's, most recent report recommended that, and I quote, "NASA would

benefit from formalizing a Design Reference Mission, or a DRM, for Artemis to define the concept of operations." A DRM is a detailed conceptual framework that outlines how a mission will be conducted, specifying objectives, the systems involved, and operational processes. Your testimony states, "NASA needs an integrated exploration campaign plan with detailed systems engineering for a simpler, more suitable"—excuse me—"more sustainable architecture." How could a Design Reference Mission inform such a campaign plan?

Dr. PACE. Thank you. That's a great question. And—first of all—and thank you to the Congress for creating the Moon to Mars Program Office. I think that was amazingly helpful. It produced more integration across the different elements. And so hopefully, you'll have someone from the Moon to Mars Program Office testify maybe at a future session. I hope that is because I think there are some great people there.

I would say the DRMs would be very much helpful—very helpful. Design Reference Missions were created for the space shuttle. There were about four of them that the program was designed around. When we did the Artemis program, got it started during the first Trump Administration, one of the things that I wanted was a three-ring binder with a bunch of Design Reference Missions in it to say what was going to actually happen. So I think NASA has done a lot of great work thinking about its architectures and variations in it. But for the really immediate term, having a set of Design Reference Missions to organize your campaign plan around, I think, would be very helpful, and I think the Moon to Mars Program Office is something that could probably do that.

Chairman BABIN. OK. Thank you. Ten years ago, a National Research Council report titled "Pathways to Exploration" stated, "The human spaceflight program in the United States had experienced considerable programmatic turbulence, with frequent and dramatic changes in program goals and mission plans in response to changes in national policies. The changes had a high cost in program resources and opportunities and imposed what many feared was an intolerable burden on already constrained human exploration budgets." A later ASAP report stated that "NASA faces another challenge that has historically led to disruption and inefficiency and arguably has impact on safety and good systems engineering." This is the challenge of starting over with new programs and directions following Administration change.

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. Another ASAP report, once again, expressed this sentiment by stating the ASAP, it reiterates the need for consistent program goals, funding, and schedules, also known as constancy of purpose. Human spaceflight and exploration are inherently challenging and risky and require far-reaching, long-term national commitment to capitalize on painstakingly achieved knowledge and to realize the results of resource investments. The lack of consistent commitment negatively impacts cost, schedule, and performance, workforce morale, process discipline, and most importantly, safety.

Mr. Dumbacher, to address this issue, President Trump issued Space Policy Directive 1 during his first Administration that maintained constancy of purpose and reaffirmed NASA's goal to return to the Moon. Can you speak, please, to continuity of purpose at this stage of the Artemis program?

Mr. DUMBACHER. Absolutely, I'm happy to. Thank you, Chairman Babin, for that question. And I will also highlight that your—the National Academies report you referred to I use in my class for the students on purpose. The—because that constancy of purpose that has been demonstrated from SPD–1, the *NASA Authorization Acts*, the bicameral, bipartisan support is absolutely critical on the execution side. That purpose, knowing what the target is and continuing toward that target is critical. The funding and the resources have to come with it. But first is the purpose. It helps keep people aligned. It helps keep people knowing where we're going, what the roadmap looks like, and where we're eventually headed.

Constancy of purpose doesn't mean I can't change down the road. As new capabilities come online, I need to be flexible. I need to take the opportunity—as new private enterprise capabilities come in, I need to be able to include those and maybe get rid of some things and bring in new. That's OK, but the purpose is still the same. I still have the constancy of purpose, and if I still have the resources, we can go make it happen.

Chairman BABIN. Thank you. Mr. Chairman, I'm out of time. I may submit this last one—last question for the record.

Chairman HARIDOPOLOS. Thank you, Mr. Chairman.

Chairman BABIN. Thank you.

Chairman HARIDOPOLOS. Next, I recognize the Representative from Oregon, Ms. Salinas, for her 5 minutes of questions.

Ms. SALINAS. Thank you, Chair Haridopolos and Ranking Member Foushee, and thank you to our witnesses for being here today.

My district includes multiple NASA contractors and subcontractors for the Artemis program. Companies like Blue Origin, Axiom, and others support a vibrant ecosystem of small businesses that contribute key components to NASA missions. From machinists like Machine Sciences and Tektronix, and software companies like Mentor Graphics and Timbercon, Oregon's 6th District really is a hub for this kind of work.

Can you expand on the value of engaging a broad aerospace supply chain, and how does it affect the cost of Artemis programs, and more broadly, what are the implications for America's economic competitiveness?

Mr. DUMBACHER. The industrial—Congresswoman, that's an excellent question, and thank you. It highlights a very important point, that it's not just scientists and engineers, it's the entire workforce that's needed to go make this happen. The industrial base, as we've seen it, has been weakened over time. We have to build it back, and major programs like Artemis and what we do on the national security side are facing those challenges every single day.

It is critical that we get the skilled technical labor that builds this hardware, that turns the ideas into reality, get them brought along. It's just as important as other Members on the team, and we have to continue to build that. We build it by doing things. We

do it by building hardware, by flying missions, by making things happen. We don't build the industrial base by talking about it.

Ms. SALINAS. Thank you. I agree. So, of course, these small suppliers hire local talent and support good jobs in my community. And when I've had the opportunity to meet with these workers, it's inspired me how inspired they are to play a role in a literal moonshot. And last Congress, I introduced a resolution to establish July 20, the anniversary of the first Apollo Moon landing, as National Moon Day because the importance of this inspirational quality of these missions I don't think should be overlooked.

Space exploration is something that brings Americans together, and it truly inspires young people to pursue careers that are critical to our economy and to technological advancements that benefits all of society. So what specifically should we be doing to better leverage NASA's space exploration and science missions to inspire children to pursue careers in STEM and ensure Artemis can similarly bring Americans together and inspire us for generations?

Dr. PACE. Well, I have a lot of students, of course, who come to university who want to get involved in space, sort of obviously engineering and policy and economics and so forth. But I think what Dr. Dumbacher was saying about we need all kinds of people to build things, you know, down in Texas, you have steelworkers building spaceships. I mean, how really cool is that? As we have new levels of technology, additive manufacturing, more flexible production lines, we want to be able to tap everybody in the U.S. economy who can potentially contribute. And so when we have regulatory burdens that get in the way of that, there's really then not that opportunity.

So we inspire students and young people by saying, here's something you can work on, but then we have to follow through and say, and by the way, the company you work for that's able to do this is—competes on the strength of what it produces, not on its ability to fill out the paperwork. And so opening up more opportunities for competition then makes that dream of participation a reality. So the two really go together, both the education part and seemingly dull things like regulatory reform.

Ms. SALINAS. Thank you. And so I just—so I think it goes hand in hand, and I don't—and I know we've talked a bit about this, so building on that, recent reports have indicated that approximately 5 percent of NASA's workforce took that fork in the road. Deferred resignation offer and additional layoffs could be in the works, and NASA has canceled programs aimed at engaging diverse populations. So I want to make sure to be very clear about, you know, giving that inspiration, but then being realistic, how will these actions from the Trump Administration affect career opportunities for early career professionals in aerospace fields in the short term, and what are the long-term workforce implications?

Mr. DUMBACHER. Well, I will also—I'll go ahead and reiterate some points made at the full Committee hearing on February 5, that it—the more—the less uncertainty, the better, and that people need to see the opportunity for their careers. They need to see how it benefits them, they need to know it's stable, and they want to know that they're working on real problems and real challenges

that matter. So I think making sure we do that is critical, and continue to build it so that we get the real work done.

The turmoil that is occurring now is causing people to question, and these are bright people that are—we need for the long haul. And what we are doing is inadvertently slowing down our ability for them to learn because they're worried about their future and that we're not over here doing and learning. So we need to get them back to the doing and learning.

Ms. SALINAS. Thank you so much. My time has expired. I'll yield back.

Chairman HARIDOPOLOS. Thank you. I now recognize the representative from Texas, Mr. Self, for his 5 minutes of questions.

Mr. SELF. Thank you, Mr. Chairman. I am new to this Committee, so I'm—as I tried to prepare, I wanted to go back to in my reading, George Bush—George W. Bush in 2004 said we would go to the Moon by 2020. Well, immediately after that, we had President Obama, who canceled programs, who—I think you mentioned Mars. I think there was an asteroid in there. Real, real simple question, how many years did the Obama destruction of this program cost us? Here we are in 2025. George W. Bush said we'd go to the Moon by 2020. How many years are we now into delay because of the Obama cancellations of programs and distractions about asteroids and Mars? Simple question, how many years delay? Y'all have been at this far longer than I have. What's your expert assessment?

Dr. PACE. Well, we were hoping to be on the Moon by 2024, so I would say certainly 20 years, if not more. I would say, you know, maybe a decade or so lost. There was progress, I would say, during the Obama Administration on some things, commercial crew capabilities.

Mr. SELF. I just asked you one question, sir.

Dr. PACE. I would say——

Mr. SELF. How about——

Dr. PACE. I would say about a decade.

Mr. SELF. A decade. Very good. Thank you. Mr. Dumbacher? Dr. Dumbacher?

Mr. DUMBACHER. Congressman, I'll put it in the category of probably about 5 years, given what we had to go from the transition of Constellation to what's now Artemis and what it took us, that down—that dip down and that restart is—was critical, but I would say 5 years, and then it's been a matter of how we've executed since then.

Mr. SELF. Yes, thank you for that. Dr. Dumbacher, you said that 2030 is remote at best. We've—I've heard a lot about speed here from the two of you, and you've been at this a long time. We've heard about the Chinese discipline in their—and I think the—what I'm getting from the two of you is you expect them to meet 2030. Yes. So in every Committee that I belong to, I hear a lot about inputs. We do this, we fund this, we study this, we—the outputs is what almost every Committee I'm more interested in than the inputs, the outputs.

So simple question to the two of you, how do we get to 2030? So talk about maybe commercial versus NASA. How do we get to

2030? Because if we've lost this decade, 5 years to decade, how do we now get to our—how do we get there?

Mr. DUMBACHER. Excellent question, Congressman, and I will tell you, it's a topic of debate, but I'll give you my opinion.

Mr. SELF. Sure.

Mr. DUMBACHER. My opinion—my hopefully informed opinion, is, No. 1, I take advantage of the hardware I already have in the barn in the hardware available in Artemis II and III to go make it happen. No. 2 is, I get myself a simplified lander so that I can get to the Moon that does not require multiple launches. The—my 40 number comes from demonstrating it twice. I have to do the whole mission twice, once uncrewed and then crewed.

Mr. SELF. Right.

Mr. DUMBACHER. I need to get that number of launches dramatically reduced. I need to go simple. So use the hardware I have available. I have to go get a small new lander to go do that——

Mr. SELF. OK.

Mr. DUMBACHER [continuing]. And—and this is another important part—I have to give the team at NASA and industry the laser focus and the urgency to make sure that I only deal with what I need to deal with. I cut back on the administrative—administrivia that they may be dealing with, dial back the risk aversion like we've talked a little bit about so that that team has the leeway to go accomplish the mission objectives, utilizing what we have available, and then go figure out what I do beyond that for the long-term sustainability.

Mr. SELF. Dr. Pace?

Dr. PACE. I think that's right, if I would simply only add one thing to that is something overlooked is communications and navigation. The Chinese are sending up relay satellites now for communicating and operating around the Moon. We have our own systems set up. There's going to be international conferences in the next 2 years looking at confirming the frequencies we're going to be operating at. So the ability to navigate, create infrastructure in and around the Moon is going to proceed whether or not humans land there. It's not going to be like the old days for Apollo. And so shaping that infrastructure, those decisions are happening really right now, and so faster progress on communications, navigation, flying, some of these experiments—I could go into some more other technical details if you want, but I think getting the organization back to where it's flying more routinely builds a culture. You can't just tell people, go take more risk.

Mr. SELF. Right.

Dr. PACE. They have to have some experience doing that. We've got to give them opportunities for flying and, as I said, just go do it.

Mr. SELF. My time is up, but I will point out we've heard regulations, we've heard risk aversion, so that's Congress' duty. How do we cut down on the regulations and the risk aversion?

I yield back.

Chairman HARIDOPOLOS. Thank you. I now recognize the Representative from Michigan, Ms. Stevens, for her 5 minutes of questions.

Ms. STEVENS. Thank you so much. And it's a delight that it's February 26, and I'm finally speaking in a Science Committee hearing. You know, we've got a lot of important topics here. And, Chair Haridopolos, we want to welcome and congratulate you to Congress. You're filling big shoes with Mr. Posey, who we loved serving with on this Committee. And we deeply care about the U.S. space race. And of course, it's also a delight to have Mr. Babin as our Chair, Zoe Lofgren still in her role, Mr. Whitesides here. We got Salinas. I love all these people. You know, we're a collective Committee.

But as I was thinking about this topic of ours, and as someone who is a very dedicated Representative from Michigan, obviously, we've got a strong automotive ecosystem, manufacturing sector, a lot of it is diversified into the supply chain of space and our grand competition. I just can't remember when we were last as a Congress talking about a space race. And maybe that was—you know, we did the 50-year anniversary of landing on the Moon when I was in my first term. That was in 2019. Now we're a handful of years on.

But when we were going into that history, we weren't looking at it from the lens of major cuts to public health. And last night, we just passed—not me, but we saw the majority unanimously—nearly unanimously vote to pass a budget resolution that would cut $880 billion potentially for Medicaid for people. And I look at that and I think, holy smokes. You know, we want to win the race to the future.

I got a lot of technical questions for you guys. Maybe I'll have to submit them as questions for the record, but I just wonder how we can be competitive and successful in this area when we can't give people the benefits they've earned, when we look at families with children who have medically complex challenges, and we're going to say you're not going to have your healthcare. And I—look, I don't often bring up healthcare in this Committee. I mean, we've been passing *CHIPS* bills and science bills up the wazoo. *Building Blocks of STEM Act* was signed by President Trump into law in—on December 24, 2019, and that was an equity bill. It was my bill with Dr. Jim Baird and some partners in the Senate.

But I just think this is really important to bring up here because if we're really going to lead as a nation, what we see and what I know that's happening back home reminds me of what was happening when COVID hit. You got an efficiency effort, which is important, because we want the best efficiency. The last hearing we had on the Space Subcommittee before the end of the last term—Chairman, you weren't here yet—but it was really important. I mean, we're looking at the bureaucracy driving us crazy in terms of sending people into outer space. And we love the idea of getting more people to the Moon. It's inspiring, it's aspirational, and it's important to our technology.

But I don't know if we can do it at the expense of people back home having heart palpitations if their school is still going to have special education, when people aren't going to be able to work. And these are my workers in Michigan. You have to—I mean, I got a company called Detroit Flex. They make these great tubes that go into the engines. They were selling in automotive for years and

years, and then one of these amazing commercial space companies, you know, has access to it.

So I think that's how I wanted to use my 5 minutes here is to make that point in this audience of very dedicated individuals who are tied in to this Artemis, which I don't want this program to flop. I wish we were talking about ways in which we could effectively use the dollar to keep it going, to trim our bureaucracy, to make us more efficient, to have leadership.

But what I'm hearing from home is you got a government that feels really unstable right now. And we're trustees of that government. We're all—you know, everyone at this dais is an elected trustee of that government.

So I'll be submitting the more technical questions for the record, and I thank you, gentlemen, for your previous service and your time here today. And I yield back.

Chairman HARIDOPOLOS. Thank you. I now recognize the Representative from California, Mr. Fong, for his 5 minutes of questions. You're recognized.

Mr. FONG. Thank you, Mr. Chairman, and thank you for hosting this important hearing today. I look forward to working with you on this Committee.

First, I wanted to highlight—I want to highlight my community's contributions to the Artemis program, specifically at the Air Force Research Laboratory's Rocket Lab at Edwards Air Force Base. Blue Origin and the Air Force have established a partnership where Blue Origin is able to use certain Air Force facilities to test Blue Origin's BE–7 engines. This helps ensure the Artemis program is successful but also leverages the private sector's speed and innovation. And to meet the challenges ahead, our Nation needs more public and private partnerships so that we can work together to achieve great things.

I did want to ask—I want to ask both of you, in your testimonies, you described the global competition, the need to act with a sense of urgency for America to win this space race, especially with the competition coming from China. You describe some of the importance that—you described the importance of leadership in space exploration in terms of our U.S. economic, national security, and scientific interest. In light of my colleague's just—statement before—maybe we can take a step back. Can you outline the importance to everyday Americans why we need to engage, why we need to win this new space race?

Dr. PACE. Well, I think at a very high level—and part of it's academic—is we need to win it in order to make sure the environment we depend on—space is critical to our economy, space is critical to our military. And if we're second in space, then we're second in being able to shape a domain that our life depends on. You can just imagine the number of ways you use space every day, everything from your GPS (Global Positioning System) to your evening news to your weather predictions to your electrical power systems, all these things that we have an infrastructure that we depend on, so we need to protect the space environment. We need to make sure the rules are there that are conducive to our interests.

But at another level, more at home in the United States and industry, space is the most important school you can go to. That is,

in order to master things in space, you have to master pretty much every aspect of technology and science to do well. And then to bring that all together into a mission that involves humans is even more driving. So it is something that drives your education, that drives your ability to manage large-scale systems. It drives manufacturing. It drives the ability to get people inspired for the next generation.

If you look at what China is doing in space, it's for a number of reasons that are fairly self-evident. They want more influence, they want to drive their industry, they want to inspire their own population, and they want to gain skills so they can dominate in other technical fields, not illogical reasons. And so we are in a large-scale competition and struggle in the world, and space is one of those things that gives us the tools necessary to win.

Mr. FONG. So I couldn't agree more. America has to win this space race. You, in your testimony, mentioned that our missions can't be one and done. They have to be repeatable and sustainable. And you've kind of touched on the regulatory burdens. You've touched on barriers. You've touched on acquisition streamlining.

I did want to ask specifically if there were specific regulations or specific provisions that you could mention, if we can dive into the weeds a little bit, that we need to examine. And I don't know if there's a level of tiers of priority that you would have. And that goes to both of you, if both of you want to answer that.

Dr. PACE. I'm sure we could bore everyone in the room by tiering down some of the regs. I think the No. 1 thing that I would say is to push responsibility down and—to the agencies and hold them accountable. Don't have a one size fits all. Take a scalpel, not just, you know, a grenade to those things and give the agencies both the leadership direction and the top cover necessary to go and experiment.

I think, as Dr. Dumbacher said, we can actually do a lot of amazing things in getting stuff done if people think that they're not going to be penalized for trying and doing that. So I think agency accountability, I think pressing things down to a lower level in the agencies, and I think those might be questions that will come up in Mr. Isaacman's confirmation hearing.

Mr. DUMBACHER. And, Congressman, I'm fully with Dr. Pace's answer. I think we recently—we're having the right kind of conversations about regulation for human spaceflight and other things via the FAA (Federal Aviation Administration) activities and some of the others that I've been familiar with, and we're working through that. And I think we need to, as Scott has said, give people the leeway and hold them accountable to go experiment, and this Nation can accomplish great things.

Mr. FONG. I want to thank you for your testimony and guidance. My time has run out, but this is critically important, especially, I think we need to tell the story of how our lives, our daily lives are impacted with space and how we need to continue to invest and continue to be dominant in this arena, especially with the competition that comes from China.

Mr. Chairman, I yield back.

Chairman HARIDOPOLOS. Thank you. I recognize the Representative from New York, Ms. Gillen, for her 5 minutes of questions.

Ms. GILLEN. Great. Well, thank you. Thank you Chairman Mike Haridopolos, my new fellow freshman, and thank you to Ranking Member Foushee, and thank you to our witnesses. I'm very much looking forward to working together in a bipartisan manner with my colleagues on this Subcommittee to strengthen the American leadership in space.

Mr. Dumbacher, as you know, the United States and China are in a race to get our astronauts back on the Moon, which has enormous stakes for our national security. I'm very concerned that, because China uses its space program to conceal military intentions under the guise of research, what are the consequences for our national security, if the U.S. and—for the United States if China is the first to land crewed mission or even establish a lab on the Moon?

Mr. DUMBACHER. Well, again, as we've discussed, it's about the presence, and it's about being there, and by being there, that's how you establish your value system, your leadership, and the rules of the road for our Nation. I think it's absolutely critical. It's also critical, even from a technical perspective and a programmatic perspective because we want to be the ones to help figure out the technologies that are so critical, not just for what Artemis needs and what NASA needs, but also for what our national security, U.S. Space Force, and others are going to require, on-orbit propellant depots; communications; power; position, nav, and tracking, all of that we want to be in the forefront so that we can build it and for the policy reasons of establishing the rules of the road via our presence.

Ms. GILLEN. Thank you. And just to follow up, earlier in your testimony, you talked about making sure that we—Congress gives you the funding you need to maintain and have our space program excel and making sure that we have the best and the brightest involved in our space program. I'm curious. We're lucky enough to have folks like my colleague beside me, Mr. Whitesides, who is a leader in our space program. What can Congress do to make sure that we have a pipeline of real talent to get our program where it needs to be and to be the future of space?

Dr. PACE. I would point out it's been more than 20 years since the Congress passed the 2004 NASA workforce bill, which produced some liberalization, allowing people to come in, some more flexibilities. I think a topic for the next Administrator is a new NASA workforce bill to look at how maybe people can go more easily to industry, from industry back in to government in a disciplined sort of way. There's been a lot of changes, and I know Dr. Dumbacher, from his AIAA experience. I think if that gets folded into a NASA authorization bill, great, but I think relooking at the NASA workforce bill after 20 years might be a good use.

Ms. GILLEN. Thank you, sir. I yield back.

Chairman HARIDOPOLOS. Thank you. I now recognize the Representative from Utah, Dr. Kennedy, for his 5 minutes of questions. You're recognized.

Mr. KENNEDY. Thank you, Mr. Chair. It's an honor to be with you and with this Committee. It's very exciting. Thank you to the witnesses for being here to consider us going to the Moon and beyond.

So in the State of Utah, Northrop Grumman's state-of-the-art facilities are central to the development of solid rocket boosters for some of the most ambitious missions we've embarked upon. These boosters are key to propelling spacecraft like NASA's Space Launch System, which is set to carry astronauts deeper into space than ever before, including the planned missions to the Moon under the Artemis program and eventually to Mars.

So, Mr. Dumbacher, if you would help me, how will the Artemis technology and knowledge for the Moon mission be leveraged for future missions to Mars and beyond?

Mr. DUMBACHER. Well, the technology that we do for the Moon is essential for being able to go to Mars because, one, we're going to learn. From a technology perspective, the transportation systems, as you've mentioned, the communication, the power, the nav, we need to realize something. Going to the Moon, I'm days away from home, going to Mars, I'm months away. It's 240,000 miles versus 35 million. So I have to learn not just the technical, how to do the communications, how to do the power, how to do the environmental control and life support. I also have to learn how to do the operations. I have to learn where the decisionmaking needs to be because of the time delays in the communication, and that the astronauts will have to react onsite and not be able to have as much help from home because of the time delay. I need to think—I need to work through all of that, and I do that by operating at the Moon, trying—going through the new mission scenarios, and then eventually going out to Mars with that knowledge.

My analogy for it is, I don't take my Girl Scouts and Boy Scouts out to the Grand Canyon on their first camping trip. I take them to the local backyard State park, and then I might go out to the local national park before I take them to the Grand Canyon. It's the same kind of thing where we need to learn along the way, and the Moon is that steppingstone for us so that we can learn how to do those things and then go to Mars.

Mr. KENNEDY. Thank you for that answer.

And, Dr. Pace, if I can ask you this question. We're, in the State of Utah, privileged to have the Space Dynamics Laboratory (SDL) at Utah State University. The SDL's talented workforce includes scientists, engineers, and business professionals dedicated to providing solutions that support all mission phases, from concept to completion. Utah State has been working closely with NASA on the robotics portion of Artemis. One of the programs they are working on with NASA's Jet Propulsion Lab is specifically a heterodyne OH lunar miniature spectrometer—go and say that three times fast—looking for water on the Moon, which is an important function associated with manned missions.

There are some major challenges that need to be overcome to go to Mars. Some close to the Administration have publicly advocated for going straight to Mars, bypassing the Moon, dismissing it since we have already been there. So my question is, is this a serious consideration by the Administration, or will the Moon continue to be the immediate focus?

Dr. PACE. Well, since I'm in academia, I really can't speak for the Administration, you know, on these things. I would say that I would look to the guidance that the Congress has already laid out.

I would look to the existing space policy in SPD–1 and space policy for 2020 that's still there. And I would think I would look to the logic of, you know, what we need to do to succeed. So I think it's fine for people to push and say, why can't we do this, why can't we do that, not simply to take things as a given, so I think responding to those questions is perfectly fine, but I think the steppingstone approach that this Congress has done over a few decades still remains the right direction.

Mr. KENNEDY. Thank you. And thank you for not speaking for the Administration. There's a lot on the left that seem to want to speak for the Administration on a regular basis about what's happening around here, but I appreciate your restraint in holding off on that.

A follow up question on that, if the Moon continues to be a focus, will emphasis be placed on the manned or robotic part of Artemis, or will it be a balanced portfolio? And either one of you, if you have an opinion about that, I'm open to it.

Mr. DUMBACHER. I think, Congressman, my thoughts on that are that it needs to be the balance program because I need to go figure out where the resources are, how much is there, and I can do a lot of this robotically, and the proper synergy between a robotic program and the human program is how we get to the best benefit. I send the scouts out robotically, and then I bring the humans, and I think the balanced portfolio is the proper answer.

Mr. KENNEDY. Thanks. I love the scout analogy. I enjoyed being a Boy Scout myself, and it sounds like you're doing good work for the young, which actually is my final question is we've had two Utah student teams in the past 2 years who were funded under the BIG Idea Challenge, which has a yearly theme to contribute to the future of the Artemis program with specific challenges in lunar operations. The 2024 BIG Idea team was from Brigham Young University, my alma mater times two, and they developed an untethered and modular inflatable robot for lunar operations. What can NASA do to enhance academic partnerships which contribute to our mission to go to the Moon, Mars, and beyond? What, in your opinion, do you think about that?

Mr. DUMBACHER. I think I will actually point to—the Office of STEM Engagement at NASA has done a tremendous job over the last several years strategically and all the way through implementation of growing that capability. They have done a masterful job of marshaling the resources, doing it efficiently and quickly, and right now, their hindrance is funding that's holding them back from being able to do more. We just need to do more.

Mr. KENNEDY. Thank you for those answers. My time has expired. Mr. Chair, I'll yield back.

Chairman HARIDOPOLOS. Thank you, Dr. Kennedy. I know we're waiting for Ms. Rivas. She's on her way, my understanding, the Congresswoman from California. We'll give her a little time, no problem.

I now recognize the Representative from California, Ms. Rivas, for her 5 minutes of questions. Welcome.

Ms. RIVAS. Thank you, Mr. Chair, for allowing me to waive on to today's hearing in your Space and Aeronautics Subcommittee.

I have deep concerns about the Trump Administration's attacks on our Federal workforce and how it will impact NASA and the Artemis campaign. Just outside my district is NASA's Jet Propulsion Laboratory. The space workforce in and around my district understand the disruption and difficulty of layoffs in the space sector all too well after JPL laid off almost 850 people last year. Any reduction to the space workforce will negatively impact our communities, our future, and our country's competitiveness.

In fact, it was the team at JPL that brought a methane leak in my district to the public's attention in 2020. JPL's report, which used airborne sensors to observe methane sources, found that the station in my district had been leaking more than 10,000 cubic feet of methane per hour for the last couple of years, equivalent to the emissions of 30,000 cars.

The Administration's proposed NASA firings and Federal funding freeze will negatively affect NASA centers and federally funded research and development centers like JPL by cutting science programs and missions that are in operation, inhibiting NASA's ability to push innovative boundaries.

Mr. Dumbacher, in your opening statement, you talk about how our workforce must be nurtured and how our strength is being able to bring out the best minds from across the country. In your experience in the space engineering industry, what will happen to our Nation's progress if the current Administration continues to move forward with their plans to reduce the space workforce and their continued insistence on the removal of the word "inclusion" as a core value of NASA?

Mr. DUMBACHER. Our workforce, the national asset that we have built in—built and invested over time requires, one, to know that there is stability for their careers and for their lives. And by us continuing in the bicameral, bipartisan way that this Congress and SPD–1 and other things have set the constancy of purpose, that's an important element. Then the funding has to come to go execute the programs. And what's important for our workforce is for them to see that they have real challenges, real problems to go solve, and they'll go do it. And then they will learn, and we will—and our society will reap the benefits. That's the important part.

And we also have to realize that in this global competition, we need to tap all of the resources across this country to be able to compete with others. Just because China has a larger population than we do, we graduate 10 to 20 percent of the number of engineers on an annual basis at the undergraduate level compared to the Chinese. We need—we're not going to win the numbers game. What we need to do is get the perspective, the talent, and tap into those communities that we haven't tapped into before to help make sure we're bringing all of the talent to bear across this country.

Ms. RIVAS. Thank you. I agree. You know, as you may know, I'm the only Latina in Congress who is an engineer. I'm also the Co-Chair of the Bipartisan Congressional STEM Education Caucus. And, you know, ensuring that all Americans, especially women and girls of color, can see the first woman and the first person of color land on the Moon is essential to the vision of this campaign. Your written opening statement mentioned that only 10 percent of our

engineering graduates are Hispanic. In your view, what needs to be done to improve this number?

Mr. DUMBACHER. What I've learned Congresswoman, is that, No. 1, they have to see the opportunity, and they have to see themselves as being able to accomplish that opportunity, and they see it through their mentors and people like them that are actually—are the astronauts, are the program managers, are the engineers, are the scientists, even the attorneys. And they need to see that capability, and then their networks, their support structure, their families, their friends, their relatives, need to also understand the opportunity and see that as an opportunity to help build it. And then we also need to help them through their educational journey because it's a challenge, and it always will be. And we need to help them through that, at the end, making sure that they see the opportunity and the real challenges and the real problems they get to solve.

Ms. RIVAS. Thank you. You know, as you can tell, these issues are personal for me, for my State, for my district. I agree that, you know, family, teachers, educators all need to be part of the solution. Thank you, and I yield back.

Chairman HARIDOPOLOS. Thank you. And I believe Congressman Collins is en route, so I'll give him a little bit of time, as we did for Congresswoman Rivas as well.

Ms. RIVAS. Thank you.

Chairman HARIDOPOLOS. I now recognize the Representative from Georgia, Mr. Collins, for his 5 minutes of questions.

Mr. COLLINS. Thank you, Mr. Chair. And I appreciate you giving me a few minutes to get in here. Somehow—I've only been coming here 2 years, but I got lost. Anybody figure Rayburn? No.

I kind of wanted to tee off of a couple things that y'all were saying in your opening testimony, and I also want to kind of intertwine that with the hearing that we had yesterday in Natural Resources because I think they kind of go hand in hand.

And as far as my background, I'm a small business person, been an entrepreneur all my life, and just started this in the 118th Congress. So I like to look at things from a small business and entrepreneurship type of frame. And I know in today's age that we are in a different light, as the Chairman said, just not productivity and efficiency, but saving the American taxpayer money, being productive, but yet being efficient at the same time. And we know that Artemis has had a few setbacks and a few problems.

But I just want to go and take a look at what's out there and what's available and where the world is going. And yesterday, when we had our hearing, there were two companies there, and I don't know if y'all—y'all may not know them or may know them. One of them was AstroForge, who is doing deep space exploration, and the other one is Starpath. And Starpath, I thought, had a really unique look on what they're—and they're simply a mining company. And we're talking about mining critical minerals and, in this case, rocket propellant fuel. And their whole niche was to make it cheaper to get to the Moon and back. In their words, they were going to be a gas station on the Moon. You know, the rocket ship, SpaceX, whoever comes lands, NASA comes and lands, and while they're doing their business, people like Starpath will check the

tires, the oil, and fill them up with propellant fuel to get them back, which we all know would save weight and save fuel.

And so what I kind of want to—and I guess, Dr. Pace, I'll ask you this question, and then I want to ask both of you the same thing. But, you know, because NASA programs, they often do struggle with staying on schedule and staying on budget. And so what is needed? And I can go over some other examples on some other Committees, where we do appropriations every year for the same project, and it just gets really crazy because it doesn't work. But what are some realistic budget program architectural things within NASA that may help?

Dr. PACE. Sure. I think something that was done in the last Trump Administration, we were trying to get the NASA budget up to roughly where it was at the end of the cold war. And if we had the same budget power today that we did around 1992, the NASA budget would be $30–33 billion, so there's been a long-term decline in the NASA budget over time.

When talking about that, the pushback that I got was, great, happy to see more money going to NASA, but show me where the innovation is. Give me something that's innovative and new, not just another program of record. I mean, that was really the challenge. So I think if you're challenging NASA to say, OK, you need more resources, first, tell me how are you going to do this in a more sort of innovative kind of way?

I think one of the ways you save money is by thinking about those things that only the government can do versus those things the private sector can do. Just like we have a U.S. Geological Survey to go out and do some basic information, I think that NASA has a role in doing basic science, understanding what resources might be there on the Moon, but as soon as possible transition over to where NASA simply buys those resources, buys it as a service from these kind of commercial companies.

So the way you do it, one is by pushing for innovation, and two, making sure that NASA only does those things that really only the government can do, and, if at all possible, to give the private sector a shot, they should get that shot.

Mr. DUMBACHER. So let me—I'm going to come from my personal experience. Scott just said the things that NASA ought to be doing when they're doing them, do it with the right size team, with a team that has the leeway to go execute on that program and has the discipline to manage that program and to make it happen on the schedule and to meet the technical objectives.

I have personal experience that I managed personally and had a small team that delivered on the objectives on schedule, 10 percent under budget, and it was the first vertical landing rocket that this country had done, and that workforce then went to SpaceX and Blue Origin. It can be done with the right discipline—the right people, the right leeway, and the right discipline.

Mr. COLLINS. Right. And I would agree with you, and I think that's where I was alluding to like with—even with Starpath. Is that—have I burned 5 minutes? Holy cow. I knew I talked slow being from the South, but—and I think that's where I was going with things like Starpath. I mean, they're talking about, they could

potentially be on the Moon by 2026. That's their goals, and to set up and start mining.

And anytime you can take a public—and I didn't know what else you saw out there, public-private partnerships that might be available that we need to be looking at up—from up here. So—well, I'm out of time. I see that. I had another question, but——

Chairman HARIDOPOLOS. Well, thank you——

Mr. COLLINS [continuing]. That's OK.

Chairman HARIDOPOLOS [continuing]. Congressman Collins.

All right. And with that, that is all of our Members here today. I want to thank the witnesses for their valuable testimony and candid opinions as well. Thank you. I want to also thank the Members for their thoughtful questions, and I look forward to working with my Ranking Member as we proceed this year. I appreciate the thoughtful comments today.

And the record will remain open for 10 days for additional comments and written questions from Members. And with that, this hearing is adjourned.

[Whereupon, at 12 p.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Scott Pace

Questions for the Record

U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON SPACE AND AERONAUTICS
"Step by Step: The Artemis Program and NASA's Path to Human Exploration of the Moon, Mars, and Beyond"
February 26, 2025

Questions for the Record from Dr. Scott Pace, Director, Space Policy Institute and Professor of the Practice of International Affairs, George Washington University

Questions submitted by Ranking Member Valerie Foushee

1. In your written statement, you indicate "NASA needs to innovate more, reduce costs associated with fixed and aging infrastructure, and leverage the private sector to create new capabilities it will want to buy." Could you elaborate on what you think needs to be done about NASA's aging infrastructure, some of which both NASA and industry utilize?

According to the NASA Office of Inspector General, NASA is one of the largest property holders in the federal government with $47 billion in physical assets and an inventory of more than 5,300 buildings and structures across 12 states and the District of Columbia. However, more than 75 percent of NASA's facilities are beyond their original design life and the agency faces a deferred maintenance backlog estimated at $5 billion as of 2023. Deferring maintenance until equipment fails has resulted in repair and replacement costs up to three times more than had NASA conducted regular maintenance.

Many, but not all, centers have master plans for updating facilities, retiring obsolete facilities, and controlling costs while executing their missions. However, NASA does not have an agency-wide master plan to repair, replace, or demolish facilities. Nor are the NASA center plans integrated with other agencies such as the departments of Defense, Energy, and the National Science Foundation. In addition to transition funding from Congress, a primary management obstacle is the concern by NASA center directors that the loss of capabilities will make them less competitive for future work assignments. In order to create an effective master plan for agency infrastructure, is it important that NASA have a stable mission direction, such as the step-by-step approach to the Moon and Mars. Second, NASA Headquarters should update the assignment of roles and missions for exploration, science, and aeronautics to the field centers. This can and should include the transition of some operations and facilities to the private sector. For example, payload and launch operations at the Wallops Flight Facility and the Kennedy Space Center could be transitioned to private sector operators.

Congress extended Enhanced Use Leasing (EUL) Authorities for NASA through the end of calendar year 2032. This was a welcome step as some NASA centers are able to use EUL authority to lease underutilized areas on its properties to other federal agencies, academic institutions, state and local governments, and private partners in space exploration, raising revenue for the agency. An agency master plan should be able to identify NASA properties as fully aligned with NASA missions, scheduled for repair or replacement, subject to EUL, identified for sale or transfer, or designated for demolition/abandonment in place. The designation of properties can and should change based on projected appropriations and missions.

A Base Realignment and Closure Commission (BRAC)–like approach to NASA facilities alone may not be successful as each facility tends to be unique with limited room for tradeoffs within NASA. Alternatively, a NASA-wide examination may be more successful if combined with similar examinations of Department of Defense, Department of Energy, and National Science Foundation facilities. A federal-wide S&T BRAC would be a different order of challenge than just NASA but may ultimately be more consequential for the nation. U.S. private industry facilities should be considered wherever possible as part of any realignment of national S&T infrastructure. While some government facilities will be unique, greater reliance on private industry could create new opportunities to cost-effectively shed federal facilities and infrastructure.

2. Can you please explain the interconnections of NASA's human exploration programs involving low Earth orbit, the Moon, and Mars?

In July 2020, the National Space Council published a report entitled "A New Era for Deep Space Exploration and Development" that detailed the intentions of Space Policy Directive 1 (2017) and the integration of human space exploration with other national interests in the National Space Policy (2020). U.S. human space exploration is proceeding in a step-by-step manner, with commercial and international partners, expanding outward from low Earth orbit, to the Moon, and then to Mars. The physical destinations are not ends in themselves, but part of building national capabilities, advancing U.S. geopolitical interests, growing the U.S. share of the space economy, and advancing scientific knowledge.

The International Space Station has enabled us to routinely live and work in space with sustained presence for a quarter century. The next step is to increase the role of the private sector in low Earth orbit with commercial space platforms while maintaining continuous U.S. presence. If the space economy is to grow and diversify away from just information services, this will happen in low Earth orbit first.

The ISS is only a few hours away from Earth and the Moon is only a few days away, but Mars is months away. The return to the Moon with commercial and international partners is meant to expand our ability to operate away from Earth and use local resources. The private sector will have a role with commercial contracts for transportation, power, and communications similar to the U.S. presence in Antarctica. The Moon will be a proving ground for both humans and robots to operate autonomously as they will need to do at Mars. At the risk of simplification, low Earth orbit is a region transitioning from government-dominated to commercial-led. The Moon is a region where activities will be initially led by governments, but with increasing roles for the private sector. Missions to Mars are exploration, even if done through government and industry cooperation. Potential commercial and economic benefits from the settlement of Mars are likely to be generational and not in the next decade or two.

At each stage, NASA's human exploration efforts will need to make judgments on how to effectively partner with and utilize international and commercial efforts. The Moon to Mars effort is too large for NASA alone to accomplish and the involvement of partners advances U.S. diplomatic and economic interests. As said in the 2020 report: "The U.S. vision for space is one in which there is a sustainable human and robotic presence across the solar system, and where there is an expanding sphere of commercial, non-governmental activities, with increasing numbers of Americans living and working in space. This vision begins with a campaign to utilize Earth's orbital environment, the

surface of the Moon, and cis-lunar space to develop the critical technologies, operational capabilities, and commercial space economy necessary for a sustainable human presence on the Moon, Mars, and beyond."

a. How important is a single destination versus an integrated exploration strategy?

A single destination is not likely to be important scientifically, economically, or politically. It is the overall expansion from the Earth to the Moon and Mars that creates benefits for the nation. The solar system is diverse and complex such that no one location is able to answer all scientific questions. The region from low Earth orbit to geosynchronous orbit is the most important for the current space economy and for the creation of new goods and services in space.

Unlike the U.S.-Soviet race to the Moon in the 1960s, human space exploration today is not about a single destination, but about expanding sustained human presence from Earth orbit, to the Moon, Mars and beyond. The purpose is not to win a one-time race, but to shape the space domain in a manner conducive to the interests of the United States and its allies. And to prevent the domination of space by malign adversaries. An exclusive focus on a single destination cannot do that.

3. In your written statement, you state that "A revised Artemis campaign plan should be a high priority for the new NASA Administrator. There may be some painful adjustments with industry and our international partners, but it is better to do so now than to continue on an unsustainable, unaffordable path." What type of revised Artemis plan and painful adjustments are you envisioning?

If NASA were authorized to proceed with a program to incentivize and purchase commercial heavy lift capabilities for the Artemis program, this would affect future purchases of the SLS. The effect would not be immediate as Artemis 2 and 3 would use SLS Block 1 but one or more private options would affect the SLS contractor work force. As mentioned in my testimony, an expendable SLS that cannot meet a goal of two flights a year is not a sustainable means of returning to the Moon.

The Lunar Gateway is an important means of continuing cooperation among the ISS partners (excluding Russia) and adding the United Arab Emirates as a new partner. However, the Gateway is not immediately needed for landing on the Moon by 2030. Thus the program schedule could be slipped to the right to accommodate NASA budget limits. Such a delay would be a hardship on the international partners who are paying for a large portion of the Gateway (the actual percentage being unclear).

China is currently planning to land on the Moon by 2030 and the ISS is scheduled to be deorbited on or before that date. If the United States believes landing an American on the Moon (and returning them safely to Earth) before China is a national priority, and if current HLS contractors are unlikely to succeed by then, then NASA could (in theory) commission a simpler government-led lander. This idea was noted by my hearing colleague, Dan Dumbacher. Such a course of action would have its own risks, as the Apollo lunar lander took seven years from contract award to first landing. Again, such a change would be disruptive to the current HLS contractors.

4. In your written statement, you note that NASA should explore alternative options to SLS for reusability. Can you share any engineering data that shows alternative options would provide the same capability as SLS?

The combined mass of the Orion and European Service Module is about 26 metric tons to the Moon, which is the capacity of the SLS Block 1. SLS Block 2 (yet to be demonstrated) should have a payload capacity of ~46 metric tons to trans-lunar injection. Depending on refueling assumptions, a SpaceX Starship might be capable of up to 100 metric tons to TLI. A Blue Origin New Glenn is currently capable of 7 metric tons and may be upgradeable. It's unclear what the TLI performance of the Relativity Space's reusable Terran-R will be. Performance is obviously crucial but the ability to achieve a steady cadence of flights is also necessary to sustain the Artemis program.

There are no alternative single-launch options to the SLS at present. That is part of the motivation to find alternative options that create dissimilar redundancy for lunar access. There are a variety of potential heavy lift options, some reusable, some not. Unlike the Apollo era when a single Saturn V was used for each lunar mission, Artemis missions already plan to use multiple vehicles (e.g., launch of Orion, HLS, and Gateway elements). Multiple private vehicles and on-orbit docking and assembly could provide alternatives to SLS 1B and 2.

a. Technically, how does the addition of reusability affect a launch vehicle's mass requirements and payload capacity?

Reusability adds to development costs and cuts into payload capacity, which is why expendable vehicles have generally been preferred. Overall costs, however, can be lower. Given sufficiently high demand, such as launching large constellations, launch vehicle reusability becomes attractive. Depending on how far a stage goes down range, reusability becomes more difficult as fuel (or wings) are required to bring the stage back. A reusable first stage is less stressing than reusing a second stage, as SpaceX demonstrated. The ability to refuel in-orbit can provide additional flexibility, for example to support a reusable "space tug" that stays in space. In-space refueling, particular for cryogenic fuels and minimizing boil-off losses, is a challenging technology in itself and has yet to be demonstrated in routine operations.

b. Would you expect NASA to fund, or partially fund, the development of alternative options, while a demonstrated capability exists?

As with commercial crew, commercial cargo, and the human landing system, I favor dissimilar redundancy in critical path segments. The same would be true for transportation from Earth orbit to lunar orbit. A Block 1 SLS has been demonstrated and the crewed SLS/Orion will hopefully be demonstrated soon. SLS Block 1B and 2 could be demonstrated, but the cost and schedule challenges are formidable. I would like to see at least one heavy lift to TLI alternative and believe it would be in NASA's interest to use milestone payments as it did with COTS. The amounts necessary would certainly require close analysis. The goal should be to provide the nation with lower cost, more frequent, and reliable lunar access for the Artemis program and other national needs compared to the status quo.

5. A study by the Center for Strategic and International Studies stated that, "There is no indication of a lunar gold rush because there are no strong revenue-generating businesses centered around cislunar activities anchored by commercial customers." Do you agree?

Yes, this is clearly true at present. The role of industry in cislunar space is in responding to government needs, providing innovative solutions, and where possible privatizing functions that in

the past might have been done by the government. An example of the latter is the private delivery of payloads to the Moon.

6. How would the prospect of NASA-only or government-only markets affect the viability of commercial efforts, commercial services approaches to obtaining lunar capabilities?

Private industry is already finding opportunities in serving government demand for lunar activities. If truly commercial activities are defined as responding to non-government demand, using private capital, and where viability lies solely with private industry, then commercial activities on the Moon are likely to be small (but not zero) for some time. Today, there are purely commercial activities in Earth orbit and we hope to find more in the transition beyond the International Space Station. We do not know what activities will be self-sustaining at the Moon and beyond. Part of the purpose of exploration, aside from science and international politics, is to learn whether we can "incorporate the solar system in our economic sphere or not" as former NASA Administrator Mike Griffin once said. Successful economic development of low Earth orbit and the Moon are also steps toward the potential settlement of Mars.

Questions submitted by Full Committee Chairman Brian Babin

1. Since 2005, Congress has established and reaffirmed that it is U.S. policy to pursue a stepping-stone approach to human space exploration, with the ultimate goal of landing humans on Mars. This approach will allow for near-term accomplishments, allow development and testing of critical space technologies and operations, and facilitate cooperation with international and commercial partners. How does the cost of a Mars mission compare with that of sustained lunar exploration?

Unfortunately, NASA has not published a life-cycle cost estimate for sustained lunar exploration or a recent estimate for a human Mars mission. NASA presently spends about $12 billion a year on human space exploration or a little under half its budget. This includes the ISS, space transportation, and the current Artemis program. The NASA OIG estimated that Artemis cost $93 billion between FY2012 and FY2025, or about $7 billion a year. If we set aside ISS costs, due to end by 2030, and assume some portion goes to commercial LEO platforms, a guess would be that Artemis will cost $10 billion a year between now and 2030, or an additional $50 billion on the $93 billion to date. Once on the Moon, sustaining operations could continue to be $7-10 billion per year. Again, as a guess, $140 billion to get to the Moon plus another $100 billion for ten years of operations for a total of $240 billion.

Estimates for a human Mars mission vary widely, but in 2015, a "ballpark" estimate for a conventional NASA effort was $230 billion for a human landing by 2035 and $142 billion for each subsequent landing. With planetary windows to Mars occurring roughly every two years, a decade might see 4 additional Mars landings. (NB – Apollo sent 9 crews to the Moon and 6 landed.) This would total about $800 billion in 2015 dollars or $1.1 trillion to today. Experience from the COTS and commercial crew efforts, plus other aerospace programs, suggest a radical "commercial" approach could be cheaper by a factor of 5 to 7. Thus a Mars effort might cost under $160 billion. Elon Musk estimated in 2019 that a settlement would require about 1 million tons of cargo to start, with a cost (based on Starship) of $100k - $140k per ton. This suggests a Mars mission cost as low as $100-$140 billion.

In short, no one knows, but a Mars effort could be comparable in cost to a sustained lunar effort but with a large cost risk. More conservatively, Mars could be 4-5 times more expensive than a sustained lunar effort. That said, a stepping stone lunar approach would bring down the technical and cost risk of going to Mars, which would allow for better future decisions as to when to pivot from an emphasis on the Moon to an emphasis on Mars.

2. In your testimony, you noted that "NASA needs to focus on those things that make no sense for the private sector to do while using the private sector to improve what NASA does." What are examples of the things that NASA should be focusing on for Artemis? How has that changed over time? And, how can NASA better leverage the private sector as it continues the program?

   Fundamentally, NASA needs to do what industry and international partners cannot do, which is to be the leader who drives systems engineering and integration (SE&I) across a complex enterprise. SE&I, along with program and project management, is an area that should remain within NASA. However, these areas are precisely those in which NASA is weakest and which need to be strengthened.

   The Artemis program for returning humans to the Moon, and building a foundation for future human missions to Mars, is very different from past NASA human spaceflight programs such as Apollo, the Space Shuttle, and ISS. These differences are due not only to the technical challenges of placing humans on regions of the Moon never before visited but also to how the work is organized. Artemis is more than a single engineering effort; it is a long-term campaign with commercial and international partners. NASA is the leader, but it does not directly fund or control all of the required efforts. NASA is now reliant on the separate actions of allies and partners. Unlike more frequent robotic missions, human spaceflight missions have offered fewer opportunities to hone systems engineering skills, yet the need for those skills is acute.

   Contributing to challenges with Artemis SE&I is a lack of skilled and experienced project and program managers in government; in particular those with systems engineering expertise and knowledge of commercial industry. There are pockets of expertise in major science programs, but that experience is rarer in human spaceflight, which tends to be dominated by operations rather than development activities. Even rarer are people who understand commercial industry practices and incentives, despite the desire of NASA to rely on the private sector to lower costs and improve productivity. Instead, there are pressures to shift costs and risks to industry without clear priorities and requirements while the agency retains ultimate control. This results in frustration on all sides.

   The next Administrator will face leadership challenges in the agency's culture and governance. On one hand, bipartisan support for Artemis has been a cause for optimism by NASA and industry that "we're really going to do this." On the other hand, there is a deep risk aversion in the workforce that has grown since the end of the Shuttle program. Unfortunately, partly as a result of political turmoil, NASA has become more "institution-driven" rather than "mission-driven." That is, the preservation of the institution has become more important to the agency than accomplishing its mission. Support from Congress, the White House, and new NASA leadership will be needed to ensure the NASA workforce has the skills and experience to be a global leader, partner, and smart customer. This requires encouraging the workforce to gain hands-on experiences with challenging missions. As mentioned in my testimony, hardware and flight tests drive out nonsense.

3. During my questions at the hearing, I appreciated hearing your perspective on the Moon to Mars Program Office. In 2022, NASA outlined several sets of Moon to Mars objectives for both deep space

destinations. These objectives covered different science areas and the development of infrastructure, transportation and habitation, and operations. In your opinion, what are NASA's most pressing objectives for the Moon to Mars Program in terms of infrastructure, transportation and habitation, and operations?

The major elements of Artemis, such as transportation, habitation, operations, etc., are major technical challenges by themselves. For example, the HLS program is necessary to land on the Moon before China. Ensuring the SLS program remains on track is critical as there are no alternative heavy-lift options, at least for the next few Artemis missions. The creation of modern communications and navigation infrastructure (e.g., LunaNet) is necessary for all human and robotic lunar operations by the United States and its partners.

But the biggest challenge is the integration of these elements with each other and across the program. The creation of the Moon-to-Mars Office was important as a means for asking hard questions and driving integration across the government, industry, and international enterprise. There needs to be a common platform for all program, systems, and acquisition managers to come together to work out systems of systems engineering and integration issues, interoperability, and interdependencies. This should include life-cycle cost estimates with joint cost-schedule confidence levels based on the technical maturity of component elements. Commercial providers are often challenged in doing integration and cost estimates as they lack sufficiently stable requirements, engineering information, or testbeds and proving grounds across the enterprise. Thus the agency has difficulty making "build or buy" decisions on what tasks should be outsourced or done in-house.

During the Apollo program, an organization known as Bellcomm was formed out of Bell Labs (the R&D arm of AT&T) to support NASA Headquarters and the Office of Manned Space Flight. Bellcomm was a 300 person organization that provided connectivity for engineering and science information exchange across all government and industry entities working on Apollo. As might be expected, there would be internal objections from NASA field centers, contractors, and internationals at such oversight today. The creation of such an organization should be offset by the consolidation and elimination of duplicative review functions – many of which did not exist during Apollo.

Questions submitted by Full Committee Ranking Member Zoe Lofgren

1. NASA's Artemis Accords have been signed by 53 nations, and over a dozen countries have agreements with NASA to provide hardware or other contributions to the Artemis effort. To what extent is the success of Artemis reliant on these international partner agreements?

   The Artemis program is not directly reliant on the Artemis Accords, which are a diplomatic and political agreement. The United States is potentially vulnerable, however, if smaller signatories to the Accords feel that they lack a meaningful role in the Artemis program or if there are no tangible benefits for them. This would potentially open the door to China, which is seeking to expand its influence beyond the Global South.

   Artemis is reliant on countries that have specific implementing agreements with NASA that cover elements such as the European Service Module, the pressurized "lunar cruiser" from Japan, and the Gateway airlock funded by the UAE, and the communications and navigation functions of LunaNet provided by Europe and Japan with NASA.

Questions submitted by Rep. Haley Stevens

1. The Space Launch System (SLS) is the only operational heavy-lift rocket capable of launching deep space missions, like Orion, into cis-lunar flight without requiring refueling in low-Earth orbit. While reusable heavy-lift rockets are essential to reducing costs and sustaining long-term U.S. leadership in space, they often currently depend on untested low-Earth orbit refueling technologies. I am concerned about some calling for a premature shift away from SLS before reusable systems and refueling technologies are fully proven. What key factors must be addressed to prevent bottlenecks with a reusable system, including those that may require LEO refueling, that could disrupt a sustained lunar mission cadence?

   All the points in the question are well taken. Cryogenic fuel transfer and management of boil off is important to the Human Landing System designs of both SpaceX and Blue Origin. These are key capabilities that, if delayed, have the potential to slow a U.S. return to the Moon. Presumably, the technologies will be matured and demonstrated prior to human landing on the Moon and be available for use by subsequent vehicles.

   As mentioned, SLS 1 should be used for Artemis 2 and 3. But it would be prudent to encourage the development of a reusable vehicle for transportation from Earth orbit to lunar orbit and return. In addition to risk reduction, an additional option for in-space transportation could enable more sustainable access to the Moon than currently demonstrated SLS production rates.

Responses by Mr. Dan Dumbacher

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

"Step by Step: The Artemis Program and NASA's Path to Human, Exploration of the Moon, Mars, and Beyond"

Mr. Daniel Dumbacher, Professor of Engineering Practice, Purdue University

Questions submitted by Ranking Member Valerie Foushee

1. The Congressionally-directed annual report of the independent Aerospace Safety Advisory Panel, or ASAP, for 2024 stated that the aggregated risk associated with accomplishing so many first-time milestones on Artemis III—the crewed lunar landing, the first of its kind since 1972—may be too high. Do you agree?

I do agree. As stated in the written testimony, "The ASAP assessment highlights 14 critical "first-time" milestones, including the development of the poorly understood and under-researched cryogenic rocket fuel storage and transfer technology. By NASA's own plan, approximately 40 large Starship Launches are necessary to first demonstrate the capability on an uncrewed mission, and then execute the first human mission currently planned for Artemis 3. The question becomes: Can 40 launches, development and demonstration of the undeveloped and undemonstrated on-orbit rocket fuel station, and integration of a complex operational scenario across multiple systems, all successfully occur by 2030? Any objective assessment, including my own view, concludes that our approach today has a very low probability to match the "before 2030" milestone for landing humans on the moon. In other words, the probability of the United States safely landing humans on the moon by 2030, with the current plan, is remote at best.

The succinct issues are the multiple launches (~40) and the on-orbit propellant storage and transfer technologies that must be developed and demonstrated. We need to find a simpler approach to have any possibility of returning U.S. astronauts to the moon in the 2030 timeframe.

   a. If so, what does NASA need to do? Stick with this high-risk approach or move to something different?

Assuming the United States wants to retain its leadership in space, including returning humans to the moon by 2030, the following recommendations are provided:

- Return humans to the moon as expeditiously as possible by utilizing existing systems such as the Space Launch System, Orion spacecraft, ground systems and existing international partnerships. This will require extreme focus by the NASA / industry Artemis team for the goal of returning to the moon by 2030, assuring the most efficient and technically rigorous efforts are accomplished. NASA must embrace the utmost sense of urgency and laser-like focus on returning humans to the moon by 2030. This will require significant disruption and acceptance of more efficient methods of doing business, "skunk works" type program management for dramatically increased decision velocity, and a dedicated, highly capable team with the requisite space systems development and operations expertise. A much simplified lander is needed compared to the current landers in development. A simplified lander using elements from current human landers and less reliance on cryogenic propellant storage is needed in the near term for 2030;
- In parallel, utilizing the growing private space capabilities, government and academia, immediately initiate the architecting and implementation of the **sustainable** and **efficient**

approach to retain the United States presence on the moon in the form of a long term lunar base, assuring our National Security and future economic opportunity, consistent with National priorities and policy, and the science priorities from the National Academies Decadal Surveys. We must also take advantage of the progress made on the human landers to date and encourage those who wish to compete for future application.

As we work toward the long-term presence, we must utilize emerging technologies and capabilities in human landers and other critical systems to achieve the vital objectives established by Congress and the law. Existing human lander efforts, technology demonstrations in communications, power, and nuclear propulsion are all necessary for U.S. leadership and long term presence at the moon.

As Dr. Pace mentioned at the hearing, we should establish a 60 day study to develop an integrated strategy. This will force the key decisions and must not allow repeated analyses. We have all the technical info we need. It is essential we get an integrated strategy for the United States to maintain and grow its long-term leadership in space.

b. If a different approach is needed, should it be done in parallel with work on the original plan or in lieu of the original approach for an Artemis III lander?

The different approach is needed for returning humans to the moon by 2030, as mentioned above. The integrated strategy must address the near-term objective of returning humans to the moon by 2030 and the objective of long-term U.S. presence in space and a lunar research station. The urgency of the global competition demands that we address the 2030 objective **and** the long-term presence objective in parallel.

This integrated strategy should very much take advantage of investments made to date where appropriate. Work to date on the human landers should be utilized wherever possible, and investments made in technology advances should also be used. It is critical that we have a true understanding of the technology development needed, based on the priorities and timing of the overall integrated strategy. This will determine detail investment priorities and timing needed to accomplish the objectives of the integrated strategy.

An overall integrated strategy, derived from the existing U.S. law and Space Policy Directive (SPD)-1, should be the clear focus and plans with measurable, rapid progress to address the urgency developed as soon as possible. We are "burning daylight" and falling behind.

2. You were in senior leadership positions at NASA while the agency and its contractor workforce experienced the uncertainty that came with the end of the Shuttle era and transition from the Constellation program. What were the impacts on the workforce, including its ability to focus on the mission and effectively execute its programs in a time of great uncertainty?

The NASA workforce during the Shuttle transition and the Constellation changes remained focused on the mission, despite the personal challenges. During these challenges, the discussion was about administration modifications to priorities and the mission. The workforce was able, with the excellent NASA leadership at the Centers, especially the Kennedy Space Center, to remain focused on executing the mission in a safe manner, and staying focused on delivering quality hardware and operations. These professionals safely flew out the final Shuttle missions recognizing that their jobs were likely to disappear. They were dedicated and true. The Constellation team focused on delivering the hardware that ultimately, following detail analyses, became the basis for Orion, the Space Launch system, and Experimental Flight Test-1. Because of their professionalism and dedication, NASA was able to establish what is now Artemis in record time.

There is a key difference to what the workforce faces today. The current turmoil is much more personal, especially in terms of the derogatory descriptions of the civil servants and contractors. Every day these professionals do their best to serve the country and the taxpayers. Now the powers creating the turmoil are personally attacking the workforce and treating them extremely unprofessionally with incoherent, and inconsistent messaging, threatening jobs, etc. We seem to have forgotten the fundamental tenet of, "treat others as you wish to be treated."

No doubt, there is the need to make better, more efficient use of precious taxpayer resources. This should always be key to the NASA team. It must also be recognized that the taxpayer representatives, the Members of Congress, have clearly spoken over the years and provided in law via authorization and appropriations the priorities for NASA. These must be addressed as demanded by our democratic principles and the U.S. Constitution.

a. To what extent do ongoing workforce disruptions at NASA, including recent executive branch actions on deferred resignations and threats of potential probationary layoffs and mass reductions in force have implications for the safety of Artemis elements and activities? Please share your perspectives.

We have seen repeatedly throughout human history how distractions can negatively affect the desired outcomes. Distractions in aircraft cockpits, distractions at nuclear power sites, and distractions driving all affect human safety. The current environment has added unnecessary distractions to the already challenging mission of safely transporting humans to orbital velocity (17,500 miles per hour) and to the moon 240,000 miles away. It is impossible to predict how the desired outcomes will be negatively affected, however, there is no doubt that when the distractions are increased, the risk to human safety increases as well. The challenges inherent in the current Artemis 3 plan include developing new technology (on-orbit propellant storage and transfer) for "rocket fuel stations on orbit," multiple launches-approximately 20 launches per mission, and all of this must work perfectly each launch. We are setting ourselves up for failure in some form with totally unnecessary turmoil. Failure is not an option with humans on board.

These distractions negatively impact an already challenging environment given the global competition. In essence, we are making it even more difficult to compete in the urgent global environment and force ourselves to be further behind our competition. We are ceding our leadership to others by distracting the valuable workforce that this nation has developed and invested in over the decades. We are causing delays, and costing the taxpayers additional resources, at the very moment when the resources of time and money are most needed and while global urgency is at peak importance.

3. Can you please explain the interconnections of NASA's human exploration programs involving low Earth orbit, the Moon, and Mars?

Each of these destinations is a step from our home - planet Earth. We are gradually, with available resources, learning how to live and work in space. Human history demonstrates the learning process by taking increasingly difficult steps. We have much to learn between the earth and the lunar surface and potential economic opportunity to derive. Humans have only explored the lunar equatorial region on the near side of the moon. We have yet to explore the polar regions and the far side of the moon.

From a technical and human point of view, going to Mars is orders of magnitude more difficult than returning to the moon, 36 million miles versus 240,000. This means that the travel time is measured in months versus days to get to the moon, and hours to get to low earth orbit.

There are significant open questions and needed capabilities to return to the moon for the long-term. We need to understand how humans live and work in the microgravity and radiation environments, and

understand the long-term psychological effects. We also need to develop and demonstrate at scale: propellant storage and transfer, locate and quantify the lunar resources necessary for our long-term presence, develop life support, power, propulsion and communications systems.

While Congress has repeatedly endorsed Mars as an eventual destination, it has also recognized in law for almost 20 years the importance of a consistent space policy that captures both the nearer-term scientific, international and commercial value of returning to the moon on a permanent basis while continuing development toward Mars. Space Policy Directive-1, and the bipartisan and bicameral agreement on continuity of purpose thus underpins our national effort to date and spurs it forward.

a. How important is a single destination versus an integrated exploration strategy?

Destinations are subsets of an overall exploration strategy and must flow from the top level strategy. We need both a strategy to achieve the policy objectives that then guides the decision processes for destinations and priorities to be accomplished. It is essential that the policy objectives, currently established in U.S. law, be accomplished with a strategy to meet these objectives, recognizing available resources. We must proceed, utilizing the strategic guidance, to determine the destinations, timing of reaching those destinations and therefore the priorities of technologies and systems to be developed and demonstrated.

4. What would be the anticipated impacts on NASA's Artemis international partners of any potential Administration proposal to significantly shift or change the goals or destinations for NASA's human exploration programs?

International partners currently look to the U.S. for leadership. They develop their own strategies, plans and resource commitments based upon the U.S. strategy. Significant alterations made to the U.S. strategy directly affects the international partners and their internal commitments. Quick changes made by the United States negatively impacts international partner planning and leads to mistrust that the U.S. will live up to its end of the partnership.

There have been many examples in space projects where our changes have led to negative international impacts. When the U.S. stepped back from the Constellation Program and the progression from the moon to Mars, international partners were forced to change their decisions and investments on returning to the moon to exploring near-earth asteroids. This decision by the United States not only wasted 2-5 years of U.S. progress and the associated precious taxpayer resources, it also forced requisite, very expensive rework by the international partners. The international community had to totally revisit its investment priorities and obligations in space exploration, thus wasting their own precious resources and loss of at the least same amount of time as the United States. This one example is a key element of why the United States and its allies are rapidly losing our leadership in space to the global competition.

a. What would be the implications of losing those international partners to other non-U.S. space exploration efforts?

Dramatic changes to the U.S. strategies and plans will encourage international partners to seek out more stable partnerships and negatively affect the U.S. leadership in space. I will note that Dr. Pace's testimony has a more thorough treatment of these concerns, and I would defer to his professional expertise. Clearly, as international capability transitions to non-U.S. partnerships, and as those countries wish to grow and prosper for their own citizens, they will choose to find partnerships beneficial to their goals and objectives. This will move strategic partnerships and needed technological capability away from the United States, and make it even more difficult for the U.S. to attain its long-term strategic objectives in space, demonstrate leadership, and assure those that share our values are working together.

5. A recent study by the Center for Strategic and International Studies stated that, "There is no indication of a lunar gold rush because there are no strong revenue-generating businesses centered around cislunar activities anchored by commercial customers." Do you agree?

I agree that we have yet to establish the clear revenue generating economic opportunities. I must also highlight the many highly capable people that are working and investing in helium 3 lunar opportunities, communications opportunities and other opportunities. Our international partners and international competitors are making significant investments in developing the future economic opportunities. Over the last decade, the amount of investment has increased substantially, a clear sign that knowledgeable people see opportunity. It is not a matter of "if" it will happen, rather it is a matter of "when". The U.S. must be present if we hope to have any share in the future economic opportunities.

a. How would the prospect of a NASA-only or government-only market affect the viability of commercial companies seeking to provide commercial lunar capabilities and services?

Past experience demonstrates how U.S. government investment in key infrastructure has spurred economic growth. I note the success of the trans-continental railway, power grids, interstate highway systems. The U.S. government investment, and being the only initial market, is a stepping-stone to future economic growth. Clearly, it is not a commercial marketplace in the true definition of "commercial" if the government is the only customer. However, it must start somewhere. Government needs and potential commercial development can provide the catalyst for future economic growth. We must recognize the need for long term investment, some failures and learning, that will lead to economic advancement. U.S. government investment is a key starting point to the future. Current and increasing investments from the private equity community clearly signal potential opportunity. This opportunity is increasingly developing the potential of commercial applications, along with addressing government needs. These opportunities must be sought out and incentivized so commercial providers are willing to tackle the risks in the aim of commercial success. Government investment and needs provide a valuable catalyst for this economic engine.

Questions submitted by Full Committee Chairman Brian Babin

1. Since 2005, Congress has established and reaffirmed that it is U.S. policy to pursue a stepping-stone approach to human space exploration, with the ultimate goal of landing humans on Mars. This approach will allow for near-term accomplishments, allow development and testing of critical space technologies and operations, and facilitate cooperation with international and commercial partners. Can you describe some of the key technologies and capabilities needed for Mars exploration that lunar exploration directly advances?

Lunar exploration will directly advance very important technologies and capabilities needed for Mars. Key capabilities in power generation and distribution, communications, environmental control and life support, and operational approaches are certainly furthered with lunar experience. Experience in microgravity, lunar soil control and human psychology are also key to eventual travel to Mars. There is the additional needed experience in addressing technical and medical challenges further from home (earth) given the needed lunar orbits and distance from earth. As humans learn to live and work in space for longer periods of time, and also learn how to develop high reliability hardware and software systems, this experience will be directly transferable to Mars exploration. Recognizing Mars is more than 100x farther from Earth, compared to the moon, the time differences in communications, decision capabilities, repair capabilities needed "on site," are initially learned at the moon, based on our experience to date, then transferred to the more and much further challenge of Mars.

All of this experience directly builds the knowledge base and capability for safe Mars exploration. Going to Mars before humans are ready across the technological, human experience and risk domains, is certain to lead to unnecessary loss of human life with little to be gained. Learning in the cis-lunar space environment provides the needed basis and learning to assure higher probabilities of success for the future exploration of Mars and beyond.

Additionally, how does conducting lunar operations buy down risk for a future Mars mission?

The learning gained from the lunar experience addresses the needed capabilities mentioned above and inherently reduces the risk of Mars exploration. Learning by doing, and incrementally building capability is the most efficient approach to overcoming more difficult challenges. This is analogous to learning how to camp and hike close to home before taking on the greater challenge of camping and hiking in the more difficult environment of the Grand Canyon.

Fundamentally it is a risk / reward calculation. The reward to go to Mars today costs us the potential space leadership and economic opportunity of the moon, thus ceding it to our global competitors. Human travel to Mars today is extremely high risk, certainly much higher risk than going to the moon. Yet the "reward" is national prestige, the U.S. made it first? Compare this reward to Chinese leadership on the moon and between earth and the moon, while the U.S. is looking back from 36 million miles away.

2. The Artemis program was established in 2017. Even in the few years since the program began, advancements in the space sector have continued to accelerate. Your testimony notes that "we must adjust as new capabilities and technologies come to fruition." Moving forward, how can Congress and NASA ensure flexibility needed to facilitate adoption of novel capabilities and technologies for Artemis while maintaining continuity of purpose?

The strategic objectives as established in U.S. law provide the continuity of purpose and Space Policy Directive-1. Congress should continue to hold NASA and others accountable to the defined strategic objectives. Additionally, Congress must assure sufficient funding to meet the objectives on the desired timeline. This funding and oversight must also include assuring the "on-ramps" for new capabilities, from new providers, to applied. An example was the Congressionally mandated National Academies Report "Pathways to Exploration". This roadmap developed by the best minds in the United States should be the benchmark Congress uses to measure progress and accountability for meeting the lawful objectives.

The approaches and strategies for achieving those objectives must have intentional "on ramps" for new capabilities to be applied when available, and able to meet the needed technical, medical, and business requirements as derived from the overall strategic objectives. There must be conscious opportunities to evaluate the needs for exploration and economic development against available or future capabilities. We must find new ways to assure that new capabilities can be demonstrated and brought to bear on the strategic objectives.

Congress should provide the top-level oversight and accountably, as representatives of the taxpayers, to assure the strategic objectives are valid, and that new capabilities are options to be used in the overall integrated approach.

Congress should require or establish for its own use, a Commission for establishing the top level approach to meet the lawful long-term strategic goals. A "60 Day study" to develop the top level approach would establish the following:

1. Assure U.S. leadership in space exploration by:
    - Returning humans to the moon NLT 2030;
    - Establishing permanent human presence on the moon;
2. Determine best path forward:
    - Utilizing current investments of NASA's Artemis Program, with Artemis II in 2026;
    - Recognizing realistic funding levels and current program element status, beginning with FY24 enacted levels.

Additionally, Congress must authorize and provide funding for a simplified lander that provides the U.S. with the highest possible probability of landing humans on the moon by 2030.

3. Last year, NASA published the Civil Space Shortfall Ranking which identified the ability to survive and operate through the lunar night as the number one shortfall out of a list of 187 technical challenges. Can you explain the importance of lunar night survival to American strategic and commercial dominance in space?

Surviving the lunar night will be necessary for developing the resources located at the lunar poles and the far side of the moon, both robotically and with humans. Nightime temperatures of (-280F) compared to daytime temperatures (+250F) and the associated differences with time (over 500F) clearly delineate the need for power and heat generation critical for surviving the lunar night. This is undoubtedly a high priority. We also must have the transportation infrastructure and systems in place to communicate and transport cargo and crew.

In addition to surviving the lunar night, we need the on-orbit propellant storage and transfer, and the ability to maneuver at any time to any place. Both are critical for commercial development, civil exploration and especially for national security. Critical technologies in power generation / distribution, communications and position, nuclear propulsion, navigation and tracking are also needed. We must remember that to be present in the long-term, the U.S. and its allies must have the ability to protect our assets, ourselves and our values. Surviving the lunar night and the other critical technologies are needed.

These technologies, capabilities, and operational schemes are also essential to assure safe human exploration to Mars and beyond. The investments made for lunar capability will provide the necessary knowledge base and experience for Mars application.

4. Your testimony spoke to the importance of reinforcing existing international partnerships as well as building new ones. What can NASA do to strengthen existing international relationships and recruit new partners?

First and foremost, NASA must assure an integrated strategy to achieve the policy objectives established in U.S. law and stick to it. This integrated strategy, with the requisite continuity of purpose, will provide a steady basis for international investment and partnership. Dramatic changes should be absolutely minimized and if needed, worked in concert with our international partners. The International Space Station has provided a sound basis for this approach. The Artemis Accords provide the next level of best practices. This experience, along with the steady investments over time toward an integrated strategy, will result in the successful long-term U.S. leadership and future economic opportunity.

> Additionally, in talking about international partnerships, you also highlighted how other nations, including U.S. allies, are contributing to Chinese space activities. How should NASA treat countries that intend to work with both the U.S. and China on space activities?

NASA should establish international partnership that incentivize our allies and other countries to want to work with us. We should not be pushing other countries away with antagonistic practices. We should be establishing incentives to have other countries want to work with the U.S. in concert with the integrated strategy for everyone's growth and success. Steady progress toward the objectives, with strong continuity of purpose, will establish the United States as the long term leader.

The incentives can take the form of clear deliverables for international partners to the overall effort, participation in the economic return, and demonstration of future technologies and capabilities important to the various countries future growth plans.

Questions submitted by Full Committee Ranking Member Zoe Lofgren

1. Under NASA's select use of public private partners, both NASA and commercial companies invest in the development of Artemis elements such as the Artemis human landing systems and next generation space suits. However, the milestone dates and associated milestone payments that NASA makes for completion of such milestones are not public. What are the implications of this lack of information transparency on such important projects?

This lack of transparency has two detrimental effects. First, the taxpayers and their representatives are not able to objectively assess progress, address challenges, and hold people and organizations accountable due to the lack of information. Given the investments of precious taxpayer resources this is unacceptable. Second, the data and information being generated by the taxpayer investment is not available to the broader community for application to multiple possible capabilities and economic opportunities. Our strength to date - from the Wright brothers through Apollo, the Space Shuttle and the International Space Station, is the broadly accessible knowledge developed by the taxpayer investment that directly leads to private enterprise risk reduction and future business opportunities.

It is important to recognize the need for proprietary data associated with private investment, however this does not mean that the government should lose all transparency. When private investment is made, proprietary information is appropriate. However, there must be significant recognition of the taxpayer investment that should benefit all companies and organizations working to address the strategic objectives. This is a difficult balancing act. Today we have gone too far compared to the balance struck in the mid-1990's and early 2000's when we used private investment in launch system technology development such as DC-XA, X-33, X-34 and X-37. Lessons learned from those activities provided the basis for the eventual commercial cargo and crew models. Private investment was made on those technologies, the knowledge was shared across the industry, thus providing entrepreneurs with knowledge - eventually leading to current reusable launch systems at SpaceX, Blue Origin and others. We have lost too much transparency given the high level of taxpayer investment. Current practice is leading to a path of over reliance on one provider in direct conflict with the desired dissimilar redundancy that has been a hallmark of U.S. success. Critical technologies discussed above, on-propellant storage and transfer, power generation and distribution, and communications must be available to the broader community for success, not establishing a government approved monopoly.

2. What are the key differences among large rockets such as the Space Launch System Starship, and New Glenn? a. How do these differences inform the roles that such rockets should play in NASA's Artemis and Moon to Mars activities?

Each system has been designed for a different set of requirements and therefore perform different functions. The Space Launch System (SLS) was designed in a time when private enterprise launch was in its very infancy. Falcon 9 had only flown once, and Falcon 1 had repeated failures. SLS was designed to transport crew and cargo to the moon with growth capabilities to transport crew and cargo to Mars, based on rigorous systems analyses at the time. It was not designed to assure a successful commercial business case.

Starship and New Glenn are designed to address business needs in delivering significant amounts of payload to low earth orbit for satellite constellations with possible application to large payload delivery to the moon and Mars. Starship and New Glenn both require new capabilities (i.e. on-orbit propellant storage and transfer) to deliver payloads to the moon and Mars. Critical technologies have yet to be developed or demonstrated at scale and are not likely, with current investment levels, to be available until the early 2030's.

The true comparison is not at the launch system level, but rather what is necessary to accomplish the desired mission and strategic objectives. For Starship or New Glenn to achieve the same mission as SLS,

they must be 1/10 to 1/20 the cost of the SLS, to account for the number of launches necessary for the mission, assuming the on-orbit propellant storage and transfer capability is available.

For the long-term integrated strategy, the U.S. must provide opportunities for capabilities such as Starship and New Glenn to compete with SLS on a mission basis. As this is accomplished, the new capabilities at more efficient cost become available for national security, commercial and civil application. This would be an example of an "on-ramp" for bringing on-line new capabilities necessary to assure U.S. presence in space. These capabilities and economic opportunities become the domain of the U.S. and its allies for the future, including establishing the desired lunar base.

b. What are the strengths and weaknesses of such systems in the context of deep space human exploration activities?

The temporary weakness is the need for the on-orbit propellant storage and transfer. Once that is addressed, and the launch systems reliability and cost are proven to deliver payload to orbit, the strength becomes the U.S. ability to more flexibly maneuver in cis lunar space for national security, commercial and civil space applications. Commercial competition then drives the efficiencies into the system, allowing the U.S. to take the next steps in the integrated strategy. As the commercial capability comes on-line, government can work toward the next horizon, Mars and beyond, address the needs, reduce technical risks, and provide the catalyst for commercial markets. This ultimately allows commercial enterprise to provide the services or products more efficiently, grow the markets and develop economic success. We are experiencing the beginning of this transition in private enterprise space today.

3. NASA's Artemis Accords have been signed by 53 nations, and several countries have agreements with NASA to provide hardware or other contribution to the Artemis effort. To what extent is the success of Artemis reliant on these international partner agreements?

The Artemis Accords are an essential basis for the future international partnership agreements and the much needed best practices among space faring nations. These best practices provide a context for tangible partnerships delivering key elements of the integrated strategy. To be clear, the Artemis Accords provide a context for developing partnerships, the partnerships and associated deliverables to meet the Artemis goals must be developed separately.

Artemis going forward requires investments from like-minded countries, bringing unique capabilities to the strategy. The Artemis Accords provide a context for behavior in which to execute the missions. Therefore, the Accords are key to the Artemis success.

Questions submitted by Rep. Haley Stevens

1. For decades, U.S. deep space exploration goals have shifted between administrations. However, President Biden built on the Artemis missions, recognizing that sustained focus—across administrations—is crucial to winning the modern space race. While missions may evolve, the overall strategy must remain stable. I am deeply concerned that abandoning the Moon-to-Mars cadence in favor of a Mars-first approach not only defies clear bipartisan Congressional intent—reaffirmed most recently in the CHIPS and Science Act—but also undermines U.S. leadership. a. How would the drastic programmatic shifts – like those needed to shift Artemis to a Mars-first approach – weaken our international partnerships and give China an opportunity to solidify its leadership in space exploration?

As stated in my testimony, repurposing to a Mars first approach fundamentally cedes U.S. leadership in space to China, and dramatically reduces our ability to participate in the eventual space economy. China has met all of its publicly stated plans within a year of proposed dates, even with predictions 10 years into the future. It would be a significant mistake to change to a Mars first approach, and not be present when the near-term future will be determined in space between the earth and the moon. I cannot overstate, in my professional opinion, the obvious mistake it would be to leave the moon, its resources and economic opportunity and the "high ground," from a national security standpoint, to the Chinese.

As for the international partnerships, changing to Mars first would dramatically change the established priorities and we would force the international partners to choose between the US and China. The U.S. would be perceived as an unreliable partner, again, because of changing our priorities. It is not clear that our existing allies and international partnerships would survive such a change.

2. The Space Launch System (SLS) is the only operational heavy-lift rocket capable of launching deep space missions, like Orion, into cis-lunar flight without requiring refueling in low-Earth orbit. While reusable heavy-lift rockets are essential to reducing costs and sustaining long-term U.S. leadership in space, they often currently depend on untested low-Earth orbit refueling technologies. You stated in your testimony that NASA should use existing systems, including the SLS, "as expeditiously as possible" to return to the lunar surface. I am concerned about some calling for a premature shift away from SLS before reusable systems and refueling technologies are fully proven. a. How would an early departure from the proven SLS hinder U.S. ambitions for sustained lunar operations?

Moving away now from existing hardware available for missions to the moon removes the U.S. ability to return humans to the moon in a timeframe competitive with the Chinese. The current complicated approach, requiring ~40 launches and development of unproven technologies in the next 5 years, is unrealistic. The U.S. has valuable hardware available to possibly meet the competition and we should make every effort to return humans to the moon in the 2030 timeframe.

As the U.S. builds to sustainable lunar operations and a lunar base, new capabilities such as Starship, New Glenn and the human landers currently in development, assuming development and demonstration of the needed technologies, should be able to compete and provide services over the long-term presence of the U.S. For the long-term, the United States should always be searching and allowing new capabilities to come on-line from the emerging private enterprise space providers.

b. What key factors must be addressed to prevent bottlenecks with a reusable system, including those that may require LEO refueling, that could disrupt a sustained lunar mission cadence?

Once the Leo refueling is addressed, cost efficiency and the commercial business case will be the key determinants. We need to remain focused on achieving the missions, in the most cost efficient manner possible. As new capabilities are developed that can be more cost efficient, the U.S. should quickly take advantage.

In the near-term, the new launch systems payload delivery, reliability and cost effectiveness must be demonstrated. Additionally, the on-orbit propellant storage and transfer is necessary for the developing commercial launch capabilities.

We must also develop the communications, position, navigation and tracking technologies, the power generation and distribution technologies along with how humans live and work in the microgravity environments. We must understand and address the human psychological aspects of being away from family, friends and home for extended periods of time. There are key priorities established by the National Academies of Science, Engineering and Medicine that should be considered in developing the priorities and funding levels.

Appendix II

Additional Material for the Record

LETTERS SUBMITTED BY REPRESENTATIVE MIKE HARIDOPOLOS

Space Frontier Foundation
1455 Pennsylvania Avenue Northwest Suite 400 Washington, DC 20004 United States

Chairman Mike Haridopolos
1039 Longworth House Office Building
Washington D.C., 20515

Ranking Member Valerie Foushee
2452 Rayburn House Office Building
Washington D.C., 20515

SPACE FRONTIER FOUNDATION

Dear Chairman Haridopolos, Ranking Member Foushee, and distinguished members of Congress,

Thank you for this opportunity to provide letter for the record for the Subcommittee's hearing, *Step by Step: The Artemis Program and NASA's Path to Human Exploration of the Moon, Mars, and Beyond*. It is our goal to provide a public interest context to the issues Congress faces in helping to set America's civil space strategy.

The Space Frontier Foundation believes that the American people deserve a civil space enterprise that boldly leads a free humanity into the space frontier to occupy the solar system. A frontier-opening approach will not only outpace the People's Republic of China's space program; it will serve as a powerful demonstration of why Western values of freedom, popular sovereignty, and capitalism are superior to Red China's 21st century restyling of the same old communist tyranny. It is not enough for America's government space agency to go further and faster than the Chinese Communist Party's government space agency. We want the American people, and democracy-loving people everywhere, to be able to explore, develop, and settle space.

At his recent inauguration, President Trump declared, "We will pursue our manifest destiny into the stars, launching American astronauts to plant the Stars and Stripes on the planet Mars." We believe that statement was an addition, not a subtraction, to America's civil space vision. Indeed, we believe the U.S. needs to boldly lead the world in every major human space domain – launch, Low Earth Orbit, cislunar space, and Mars – in order to dominate the future. And while progress in the first helps enable the second, and so on, these need to be worked on in parallel, not sequentially.

First in Launch – Thanks to American private investment and previous policy reforms championed by this Committee, the U.S. has won a vast share of the global launch market. But hostile adversaries like China are moving quickly with a quasi-commercial approach that provides their "companies" with unlimited access to State funds. We cannot assume that continued U.S. dominance is a given. We must ambitiously pursue every opportunity to press our *current* advantage and build on it. Therefore, we recommend making ultra-low-cost access to space an explicit national priority. There are multiple U.S. companies working to transform the economics of launch, and some are already flying prototypes. We need a vibrant, innovative,

Space Frontier Foundation
1455 Pennsylvania Avenue Northwest Suite 400 Washington, DC 20004 United States

competitive industry increasing capability and affordability across all market segments of space transportation with enabling regulations and low barriers to entry.

The Trump administration could easily partner with our commercial launch sector to accelerate innovation, continue to improve reliability and resultant safety, fund appropriate infrastructure, and streamline the DOT licensing process. But the federal government would be supporting, not dictating. Incentivizing, not managing. Instead of the European approach of trying to own and manage launch supply, NASA and other space agencies should promote new and ambitious public and private sector applications for that launch capacity by fostering new markets for new commercial space goods and services.

SPACE FRONTIER
FOUNDATION

First in LEO Development – The International Space Station, a testament to U.S. technological and diplomatic ingenuity initiated four decades ago by President Reagan, has served us well as America's beachhead in low Earth Orbit. But as its retirement looms at the end of this decade, our next logical step must be an ambitious leap: transitioning from a single, government-funded space station to a complementary network of organic, privately-owned orbital platforms that add up to much more than ISS' limited capabilities. These Commercial Low Earth Orbit (LEO) Destinations (CLDs) will serve not only NASA's needs but a growing list of public and private users eager to use the space environment to innovate and serve new customers and stakeholders.

These new orbital hubs will host scientific research, facilitate economic activity, and incubate new industries that we can scarcely imagine today. If the Administration and Congress accelerate NASA's transition to CLDs and ramp down our dependence on the ISS, we can ensure the presence of not just astronauts but an entire ecosystem of scientists, entrepreneurs, and industrial pioneers in space. A flourishing LEO economy will be the engine that powers America's leadership in the broader space economy.

First to Lunar Markets – China has set its sights on the Moon, and its 'taikonauts' will likely set foot there within five years. Should our response to this challenge be a replay of Apollo— rushing back for a fleeting moment of glory— only to leave the lunar surface for others with more ambition and perseverance to develop and settle?

No. America's vision must be far bolder. We must realize that the real competition is accessing and exploiting the high ground and resources of the moon. If we expand our economy into cislunar space, building outposts and then communities of lunar pioneers, we will win the real prize: leading the industrial development and human settlement of Earth's Moon.

First for Mars – America has a proud history of robotic exploration of the red planet. But the horizon goal of sending humans to Mars is always just over the horizon. Perhaps people want to delay the culmination of actually planting the flag, seeing it as the end of something. But the flag is a bold claim that we humans seek to expand our civilization to another world. Mars is where we will permanently expand life itself, creating a new offspring of our precious blue marble of Earth. Mars is where the American experiment will leap ahead toward the rest of the Solar System, and yes, eventually worlds around other stars.

Space Frontier Foundation
1455 Pennsylvania Avenue Northwest Suite 400 Washington, DC 20004 United States

U.S.-led human missions to Mars cannot be a repeat of Apollo. It's not about outdoing what we have already done, it's about doing what humanity has never done before. Early humans explored and migrated to new lands, but those lands already had life. Mars does not have a breathable atmosphere or edible flora and fauna. We must create a biosphere where there is none and transplant our society to that new home. Mars will require the full talents and energies of Western civilization to expand humanity to a new second planet. It's not something that one federal agency or even national government can plan out in detail; it will require a lot of different experiments and approaches. If some private company initiates its own Mars effort, then government should not only enable it but avail taxpayers of opportunities for financial and technological leverage, just as NASA buys rides for experiments on board suborbital reusable launch vehicles and commercial lunar landers today.

SPACE FRONTIER
FOUNDATION

The Time is Now

Human spaceflight is not just a series of connected actions. It is not a project or program. It is a gloriously chaotic birthing process for a spacefaring civilization. The space frontier is a continuing test of our leadership, our values, and our vision. The technology necessary to economically develop and permanently settle space is being developed now, not twenty years from now. Whether it's the Moon, Mars, or other planetary bodies and stars beyond, humans will one day develop and settle these places. The question is whether they do this as an expression of values like freedom, opportunity, and innovation—or some darker, more hierarchically-controlled and static ideology.

We believe America, a nation born in turmoil on the edge of a New World, must lead humanity into President Kennedy's New Frontier. That will not only ensure our nation's prosperity and security here at home, but grant generations hence a legacy of hope and opportunity for millennia to come. At stake is not just Artemis or NASA or even scientific knowledge, but the future of western civilization. That should be the measure of what we do today in 2025.

If you wish additional comments or questions, feel free to reach out to myself (aaron.oesterle@spacefrontier.org) at any point.

Sincerely,

Aaron Oesterle
Policy Director

THE COALITION FOR DEEP SPACE EXPLORATION

February 26, 2025

The Honorable Brian Babin
United States House of Representatives
Committee on Science, Space, and Technology
2321 Rayburn HOB
Washington, DC 20515

The Honorable Zoe Lofgren
United States House of Representatives
Committee on Science, Space, and Technology
2321 Rayburn HOB
Washington, DC 20515

The Honorable Mike Haridopolos
United States House of Representatives
Space and Aeronautics Subcommittee
2321 Rayburn HOB
Washington, DC 20515

The Honorable Valerie Foushee
United States House of Representatives
Space and Aeronautics Subcommittee
2321 Rayburn HOB
Washington, DC 20515

Dear Chairman Babin, Ranking Member Lofgren, Subcommittee Chairman Haridopolos, and Ranking Member Foushee,

On behalf of the over 40 members of the Coalition for Deep Space Exploration (CDSE), we are providing the following letter to be included as part of the record for the House Committee on Science, Space, and Technology's Space and Aeronautics Subcommittee Hearing entitled "Step by Step: The Artemis Program and NASA's Path to Human Exploration of the Moon, Mars, and Beyond". CDSE is pleased that this Committee is highlighting the step-by-step nature of exploration that will maintain the leadership of the United States in space.

CDSE is the only industry organization representing the companies directly associated with NASA's Artemis program. From small businesses and suppliers nationwide, to the prime companies that integrate and assemble them all to make the Artemis missions possible, each plays a critical step in making human exploration possible.

The Moon is not a detour on the path to the human exploration of deep space. It is the essential next step in expanding humanity's reach into the solar system. For the United States to maintain its leadership in human space exploration, prioritizing the Moon is both strategic and necessary. If years of planning by NASA and its partners in industry and across the globe for Artemis are abandoned in favor of an immediate pivot to Mars, there will be a direct impact on the very industry that NASA relies upon to accomplish its goals. The country will also surrender the Moon to our adversaries giving them the power to establish dominance, set the rules, and dictate the future of lunar exploration and resource utilization, leaving the U.S. at a severe disadvantage.

The next step in human exploration is the Moon, and doing so will enable a future where the exploration of Mars can be achievable.

Step by step is a fitting description of NASA's approach to returning to the Moon and preparing for the eventual human exploration of Mars. It encompasses not only the logical and rational progression of human exploration but also the expansion of our country's influence on this planet as we move beyond our Earthly bonds. Most people will never leave this planet, yet it is these same people who will make our return to the Moon and eventually Mars possible.

Establishing a permanent presence on the Moon will require regular and reliable transport of crews and supplies to develop the infrastructure in cis-lunar orbit and on the lunar surface, including habitats, power generation, and vehicles necessary to explore and discover. The flight-proven Space Launch System and Orion spacecraft are currently being assembled at the Kennedy Space Center to support the upcoming Artemis II mission preparing to carry astronauts back to cis-lunar space for the first time in 50 years. After that mission, the next step will be a crewed landing on the Moon. The flight hardware for that mission, Artemis III, and for subsequent Artemis missions is already in production.

The full transit system will soon be in place, including the Human Landing System still in development and test, and NASA's trailblazing activities will pave the way for future commercial interests as they recognize opportunities. We have seen this scenario play out with the ISS playing a role as the catalyst for LEO development of commercial capabilities. Extending this model to the Moon will naturally lead to the human exploration of Mars. The creativity and drive of our space industry will undoubtedly expand our capabilities and leadership as we explore and live on the Moon.

NASA's plan for Artemis draws upon the talents and capabilities of the space industry nurtured over decades. Over that time, talent developed by NASA and within the industry has brought new companies and technologies to life, enabling the continued leadership of the United States in space. Today, NASA's $8 billion annual investment in NASA's Moon to Mars activities returns over $24 billion in economic output representing a three-to-one ratio of dollars invested to economic benefit. Returning to the Moon has allowed for the resurrection of the industrial supplier, catalyzed reinvestment in technical workers of all skill sets, and has modernized supply chain infrastructure. It allows the industrial base to continue its efforts of supporting exploration but also turning the development of those skills and capabilities into applications across the economy.

However, we are not alone in recognizing that the next step in exploration is the Moon. China has set its sights on human exploration and is steadily making progress toward its own lunar aspirations to land humans on the moon by 2030.

The expansion of space activities by China could gradually undermine the national security, economic strength, and global influence that the United States has long maintained through its leadership in space. Only by initially sending astronauts to the Moon for establishment of a permanent presence with a logistics hub for exploration of Mars and beyond will the United

States remain the preeminent space power, safeguarding its national security at the lunar high ground and ensuring standards for peaceful exploration, scientific research, and use of lunar resources, in accordance with international law.

If the United States is to ignore China's rise in the space domain and its interests in the Moon and pivot to Mars, the country will cede what is seen as the most natural next step in exploration. In an era where space dominance translates to geopolitical power, failing to secure a leadership position on the Moon could mean losing ground not just in space exploration, but in global diplomacy, security, and economic competitiveness for decades to come.

Humans have always been explorers, drawn to unknown frontiers and the United States has led the world in space because exploration is a part of our national character. It is in our nature as a country to discover what is beyond the horizon.

For humanity's next steps into space, the next adventure lies not in another flags and footprints endeavor, but in establishing an ongoing presence on the Moon. It will serve as the next training ground for exploring Mars and extending humanity's reach into the solar system.

Chairman Babin stated in a House Science, Space and Technology Committee hearing by the Subcommittee on Space and Aeronautics hearing on Sept 18, 2019, "Returning to the Moon does not have to mean delaying a mission to Mars. On the contrary, it is a logical step that enables exploration of the red planet and beyond."

The truth of that statement 5 years ago has not changed.

Sincerely,

Allen Cutler

Allen Cutler
President and CEO
Coalition for Deep Space Exploration

○