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Statement of

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and

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

Overview

Chair Horn and Members of the Committee, we are pleased to have this opportunity to discuss the latest developments in the NASA Exploration Campaign. Space Policy Directive-1 (SPD-1) directs the NASA Administrator to "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term, sustainable exploration and utilization, followed by human missions to Mars and other destinations." Our pursuit of these objectives will enable America to achieve strategic presence on the Moon and preeminence in cislunar space. NASA has laid out a clear plan for NASA's Exploration Campaign that cuts across three strategic areas: low Earth Orbit (LEO), the Moon, and Mars and beyond.

Exploring the Moon strengthens American leadership in science, exploration, technology and innovation, and provides a chance for an economic revolution:

- Just as Apollo inspired a generation, NASA continues to inspire with feats of science and exploration today. If we bring together the capabilities and resources of our international and commercial partners to return to the Moon and continue to Mars, we will demonstrate to young people around the world the power of a unified purpose – an example of what humankind can do when it comes together to achieve a common goal for the common good.

- The Moon is a treasure chest of science and knowledge we can acquire with a sustained human and robotic presence. The lunar samples returned during the Apollo Program dramatically changed our view of the solar system, and scientists continue to unlock new secrets from the samples. We believe the poles of the Moon hold millions of tons of water ice. The farther

humans venture into space, the more important it becomes to manufacture materials and products with local resources. We know the Moon can tell us more about our own planet, and even our own sun.

- Exploration is critical to the continuation of our species. Humanity must build a pathway to enable settlements beyond Earth, and the Moon is a testbed for Mars. It provides an opportunity to demonstrate new technologies that we will use on crewed Mars missions: power and propulsion systems, human habitats, in-space manufacturing, life support systems, *in situ* resource utilization. Just as important, it provides a nearby opportunity to test new approaches to designing our programs so that we can cost-effectively, expeditiously, and safely expand the envelope of human activity in the solar system.

- We're laying the groundwork for the next economic revolution – a revolution which will happen in space, built on mining, tourism, and scientific research that will power and empower countless future generations and create new jobs and industries. Our investments in revolutionary, American-made technologies today fuel tomorrow's innovation and space economy.

We are pursuing the goals established by SPD-1 and the NASA Transition Authorization Act of 2017 with a new sense of urgency. We are going to land the first woman and the next man on the Moon near the South Pole by 2024. The architecture to support human landings on the Moon in 2024 is based on the architecture already in development to support our previous goal to land on the Moon in 2028. The landing in 2024 will use the Space Launch System (SLS) and Orion crew vehicle already being developed as the backbone of our deep space exploration architecture. NASA is now engaged in intensive discussions and analysis to produce the resource estimates and detailed schedules that will support the 2024 landing. Our initial focus will be on speed, working toward long-term sustainability and continuously expanding on the broader commercial, science, academia and international partnerships that will support our horizon goal: human missions to Mars.

PHASE 1: Moon to Mars (M2M): 2024 – A New Urgency

NASA is going forward to the Moon. On March 26, 2019, the Vice President announced at a meeting of the National Space Council in Huntsville, Alabama, that, at the direction of the President of the United States, it is the stated policy of the United States of America to return American astronauts to the Moon within five years and that, when the first American astronauts return to the lunar surface, they will take their first steps on the Moon's South Pole. NASA is developing a plan to accomplish this charge and will submit a FY 2020 Budget Amendment in the near future for necessary expenses to accelerate activities to establish a United States presence on the Moon by 2024. Our goal is to leverage and build upon our existing work and plans to achieve these new goals.

Schedule performance by SLS and Orion are critical to achieving a human return to the Moon by 2024. In early March, the Human Exploration and Operations Mission Directorate (HEOMD) chartered an assessment to evaluate alternate approaches for hardware processing and facilities utilization for key components, with the goal of maintaining an early as possible EM-1 launch date. To date the following has been concluded:

- The 45-day study identified production and operations opportunities that help offset schedule delays for EM-1 while identifying minimal change to the risk posture.

- An alternate assembly plan has been adopted to assemble the entire Core Stage in parallel with the engine section, then mate the engine section horizontally. Vertical final outfitting will occur at Stennis Space Center. This alternate assembly approach will result in reducing the time the vehicle will be at Michoud Assembly Facility by approximately 3.5 months.

- Orion will remove propellant and consumables not needed for the EM-1 mission; this reduction in Orion mass will provide up to three days of additional launch window opportunities.

- Even with the changes described above, it will not be possible to meet the previously-planned EM-1 launch target of no earlier than (NET) June 2020. NASA and its contractors are working to address the programs' performance issues and prevent further delays.

Next, an independent schedule risk review led by the NASA Office of the Chief Financial Officer will evaluate the HEOMD assessment and build on it to include the integrated, detailed schedule and associated risk factors ahead of EM-1. NASA leadership will review the results of these assessments in late spring 2019 at an Agency Program Management Council, before revisiting the EM-1 and EM-2 launch planning dates.

The EM-1 schedule is important, but using EM-1 to discover early design problems is more important. Launching EM-1 early and missing key tests could delay our overall objective for 2024. A successful lunar campaign is a series of missions and not an individual flight. EM-1 will be followed in 2022 by EM-2, a crewed mission with SLS and Orion to the lunar vicinity to test critical systems and lay the foundation for a lunar surface landing by 2024. We will continually assess commercial options for later missions. Having multiple transportation options has proven to be very valuable in other contexts and will be important to maintaining cost-effective, reliable access to the Moon and other locations.

A second component of our exploration architecture is the Gateway. The Gateway will function as a mobile base camp from which NASA, its international partners, and its commercial partners, can mount robotic and human expeditions to and around the Moon. Given the urgency of the human landing in 2024, NASA and its partners will focus initially on developing and deploying the Gateway's two initial components: the Power and Propulsion Element (PPE) and a minimal habitation element. Both of these modules will be launched on commercial launch vehicles. Future Gateway elements will be focused on sustainability, with new capabilities added incrementally as needed.

For missions to the lunar surface, the current plan is for astronauts to employ a transfer vehicle to travel from the Gateway to low lunar orbit, a descent vehicle to land on the surface of the Moon, and an ascent vehicle to return to the Gateway. The vehicles will be developed by the private sector and procured by NASA. NASA is moving rapidly to support development of these critical pieces of the exploration architecture. NASA previously planned to release a solicitation for an ascent module, but in response to the acceleration of the HLS to 2024, we updated our plans and will seek proposals from U.S. industry in support of rapid development, integration, and crewed demonstration of the Lander elements as a functional human landing system that can fulfill NASA and industry requirements for 2024. Using this approach will enable rapid development and flight demonstrations of human lunar landers.

NASA has proposed establishment of a new Moon to Mars Mission Directorate, which will manage systems development and technology investments for programs critical to the Agency's Exploration Campaign in an integrated manner, including all key lunar and cislunar activities as well as all technology development and demonstration activities.

Exploration Campaign

Based on the objectives in SPD-1, the *National Space Exploration Campaign Report*, submitted to Congress in September 2018, laid out five strategic goals for NASA's near-term exploration:

1. Transition U.S. human spaceflight in LEO to commercial operations that support NASA and the needs of an emerging commercial economy;
2. Lead the emplacement of capabilities that support lunar surface operations and facilitate missions beyond cislunar space;
3. Foster scientific discovery and characterization of lunar resources through a series of robotic missions;
4. Return U.S. astronauts to the surface of the Moon for a sustained campaign of exploration and utilization; and
5. Demonstrate on the Moon the capabilities required for human missions to Mars and other destinations.

The Exploration Campaign leverages a diverse array of human and robotic assets. It builds on more than 18 years of Americans and our international partners living and working continuously on the International Space Station (ISS). It leverages the advances made in commercial launch vehicle capabilities, robotics, and other technologies. With the launch of the Orion capsule and SLS rocket, as well as supporting launches of commercial rockets, NASA will expand human exploration to cislunar space and the surface of the Moon. As part of the Campaign, we also will begin sending increasingly capable robotic missions to the lunar surface in the next two years. Developed by U.S. commercial companies, these spacecraft will conduct scientific investigations, characterize resources, and provide lunar landing services to customers from America and around the world. We will also continue to execute sophisticated robotic missions to Mars while we work to develop and demonstrate the deep space capabilities required to safely send a human crew to the Red Planet.

Activities across the LEO, Moon and Mars domains are closely related and mutually supportive. For example, NASA's drive to conduct robotic and human exploration of the Moon informs the research and technology development we will conduct on the ISS and potential future orbital platforms, as well as the development of technologies needed for future Mars missions. Likewise, current and future robotic missions will provide vital science, reconnaissance, and technology demonstrations in support of future human exploration, in addition to their science objectives. NASA is actively working now to support sustainable exploration and development over the coming decades in all three domains.

ISS and LEO Commercialization

NASA is working to expand Government and commercial access to space, and to lay the foundation to support future commercial operations in LEO. These activities support existing and future space operations, commercialization, and space and flight support capabilities for NASA and non-NASA missions.

NASA's industry partners are routinely launching and returning cargo to and from Earth, and NASA is building upon that partnership with commercial crew launches to and from the ISS.

NASA will continue its mission in LEO with the ISS to enable exploration with humans to the Moon and on to Mars, continuing to perform research that benefits humanity, supporting National Lab research by private industry and other organizations, and working towards reducing operations and maintenance costs. The Commercial LEO Development effort is providing resources for NASA to assist industry in

developing a commercial LEO presence, with and without crews. As these new commercial capabilities are deployed in orbit, NASA will transition its LEO activities to employ them. Together, NASA's ISS and Commercial LEO Development efforts will lay the foundation for a future in which NASA is one of many customers of an industry-led human spaceflight enterprise.

Exploration Technology

Exploration Technology funds critical technology development to enable the Exploration Campaign, including high-power solar electric propulsion, precision landing, and cryogenic fluid management and transfer. Research and development of new technologies and capabilities lay the groundwork for enhancing and enabling lunar and deep space exploration. Exploration Technology also funds the Lunar Surface Innovation Initiative as well as technology research and development projects along the entire Technology Readiness Level spectrum that align with NASA exploration needs and support commercial expansion in space. The Lunar Surface Innovation Initiative serves as a catalyst for lunar surface technology development priorities such as: surface power, *in situ* resource utilization (ISRU), autonomous operations, and extreme environment technology. NASA is implementing this initiative by embracing competition and partnerships with industry, universities, and other Government agencies. Exploration Technology will enable NASA's workforce, in concert with industry and academia, to focus on innovative ways to further humankind's space activities from conception to testing to spaceflight.

Scientific Exploration

NASA's Science Mission Directorate (SMD) will continue its efforts to explore and enhance scientific discovery. In the context of the Exploration Campaign, this includes the Lunar Development & Exploration Program (LDEP) and the Mars Sample Return mission. NASA intends to also work with international and commercial partners in these endeavors, delivering meaningful scientific exploration and technology development work in a cost-effective way.

NASA is developing a series of instruments, experiments, and other payloads for robotic precursor lunar missions to the surface of the Moon, utilizing innovative acquisition approaches to engage U.S. industry capabilities as the Agency moves toward human exploration of the lunar surface. In November 2018, NASA selected nine companies as part of the Commercial Lunar Payload Services (CLPS) procurement, making them eligible to provide transportation services to the lunar surface for science, technology, and exploration payloads. In February 2019, NASA selected thirteen NASA-provided payloads that could be flown on the early CLPS missions. Last week, NASA received proposals from the CLPS providers for the first commercial delivery service to transport some of these payloads to the lunar surface. This ground-breaking service will be awarded later this month, leading the way for America's return to the surface. These missions will enable new science and demonstrate new technologies supporting sustainable human return to the lunar surface.

NASA will advance robotic access to Mars in preparation for human exploration. The Agency will continue to execute sophisticated robotic missions to Mars while we work to develop and demonstrate the deep space capabilities required to safely send a human crew to the Red Planet (e.g., demonstrate technology to produce oxygen from Mars resources, critical for future human Mars missions). This will include continuing the search for life with the Mars 2020 rover, and a Mars Sample Return mission launching from Earth as early as 2026.

PHASE 2: Sustainability on the Moon – An Abiding Legacy

A sustainable exploration plan requires that we build using realistically available resources. We are designing an open, durable, reusable, and cost-effective architecture that will support exploration for decades to come. Phase 2 of our plan – achieving sustainability on the Moon – also requires partnerships from across the commercial sector and around the world, as well as reducing costs in all three human spaceflight domains. Through reduction in costs, the Agency can invest in future deep space capabilities and use the new capabilities to conduct successful exploration missions. Sustainability also includes the ability of our infrastructure, capabilities, and facilities to effectively and efficiently support our missions, while including sufficient flexibility to meet future needs as we continue to explore. Finally, sustainability requires that we remain focused on the next goal beyond the Moon. Systems and programmatic techniques we develop for lunar exploration will be designed to contribute to a human exploration mission to Mars where feasible.

As noted earlier, one component of establishing sustained American presence and infrastructure on and around the Moon is the Gateway, a spacecraft assembled in cislunar space that will be used as a staging point for missions to the lunar surface and to deep space destinations. The Gateway will not be continuously occupied like the ISS. NASA currently envisions crew visits approximately once per year, so a strong focus is placed on robotic activities and infrastructure to foster ongoing investigations and operations that can operate autonomously between crew visits.

NASA's access to the Moon and its resources must be sustainable over the long haul. This does not require a permanent human presence around or on the Moon, but it does require the ability to cost-effectively access the Moon, conduct a variety of operations on or near the Moon, and return safely to Earth as requirements dictate and opportunities arise. Therefore, we will enhance Gateway's capabilities with our international and commercial partners with the goal of making lunar presence and activities sustainable. Future investments in the Gateway would contribute to lunar sustainability by enhancing resupply and the ability to conduct extended uncrewed operations and, using its solar-electric PPE, allowing us to access more regions and science opportunities on the Moon than ever before. In a Near-Rectilinear Halo Orbit around the Moon, we will have constant communications with the Earth, benign thermal effects, and the ability to abort from the surface of the Moon to the Gateway. While minimal at first, over time the Gateway will provide opportunities to conduct broad scientific research.

Gateway will be followed by other assets that would enable sustainability, such as reusable landers, reusable tugs, and rovers that will allow people to live on the Moon for extended durations, reduce the cost per person of reaching and operating on the Moon, and take advantage of the Moon as an analogue for Mars. The Moon is the proving ground for the technologies, capabilities, and programmatic techniques we will need to safely explore Mars. Per SPD-1, we are going to utilize the resources of the Moon including the water ice that is available to use for life support, water to drink, air to breathe, and also rocket fuel. Ultimately, the Moon will serve as a stepping-stone, a training ground, and a platform to strengthen commercial and international partnerships and prepare for future human missions to Mars and other destinations.

Conclusion

NASA's Exploration Campaign will create an architecture that is open, sustainable, and agile across LEO, the Moon and Mars. This year, the SLS and Orion, critical components of our exploration architecture, will reach important milestones in construction and testing as the program works through development challenges. We have called on American companies to help design and develop human lunar servives for

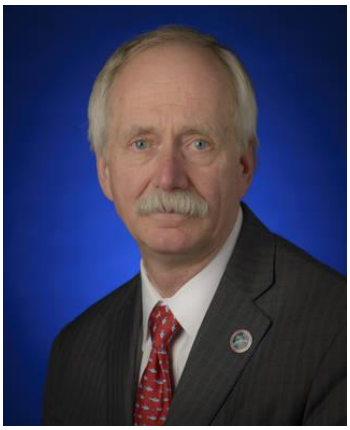
surface activities. We will continue to build commercial and international partnerships into our Gateway and lunar surface concepts to promote sustainable exploration. We are advancing our scientific knowledge and technology development with our partners through robotic precursors on the Moon and Mars. In LEO, our Commercial Crew Program continues to take strides and will soon be delivering American astronauts, on American rockets, from American soil to the ISS for the first time since 2011.

Through these activities, NASA's will realize exploration opportunities in the near-term, achieve strategic presence on the Moon and preeminence in cislunar space, and continue American space leadership for decades to come. This will empower American global leadership, spur innovation, and expand economic growth.

There's a lot of excitement about our plans and also a lot of hard work and challenges ahead, but we know the NASA workforce and our partners are up to it. The Agency is ready for the challenge of moving forward to the Moon – this time to stay. We will work to ensure that the United States quickly, safely, and cost-effectively attains our goals for 2024 and beyond.

Thank you for the opportunity to testify before you today and we look forward to answering your questions.

William H. Gerstenmaier, Associate Administrator, Human Exploration and Operations



William H. Gerstenmaier is the associate administrator for the Human Exploration and Operations Mission Directorate at NASA Headquarters in Washington. In this position, Gerstenmaier provides strategic direction for all aspects of NASA's human exploration of space and cross-agency space support functions of space communications and space launch vehicles. He provides programmatic direction for the operation and utilization of the International Space Station and its crew; development of the Gateway, Space Launch System and Orion spacecraft; and is providing strategic guidance and direction for the commercial crew and cargo programs. Working with commercial and international partners, NASA will lead a sustainable return to the surface of the Moon.

Gerstenmaier began his NASA career in 1977 at the then Lewis Research Center in Cleveland, performing aeronautical research. He was involved with the wind tunnel tests that were used to develop the calibration curves for the air data probes used during entry on the Space Shuttle.

Beginning in 1988, Gerstenmaier headed the Orbital Maneuvering Vehicle (OMV) Operations Office, Systems Division at the Johnson Space Center. He was responsible for all aspects of OMV operations at Johnson, including development of a ground control center and training facility for OMV, operations support to vehicle development, and personnel and procedures development to support OMV operations. Subsequently he headed the Space Shuttle/Space Station Freedom Assembly Operations Office, Operations Division. He was responsible for resolving technical assembly issues and developing assembly strategies.

Gerstenmaier also served as Shuttle/Mir Program operations manager. In this role, he was the primary interface to the Russian Space Agency for operational issues, negotiating all protocols used in support of operations during the Shuttle/Mir missions. In addition, he supported NASA 2 operations in Russia, from January through September 1996 including responsibility for daily activities, as well as the health and safety of the NASA crewmember on space station Mir. He scheduled science activities, public affairs activities, monitored Mir systems, and communicated with the NASA astronaut on Mir.

In 1998, Gerstenmaier was named manager, Space Shuttle Program Integration, responsible for the overall management, integration, and operations of the Space Shuttle Program. This included development and operations of all Space Shuttle elements, including the orbiter, external tank, solid rocket boosters, and Space Shuttle main engines, as well as the facilities required to support ground processing and flight operations.

In December 2000, Gerstenmaier was named deputy manager, ISS Program, and two years later became manager. He was responsible for the day-to-day management, development, integration, and operation of the space station. This included the design, manufacturing, testing, and delivery of complex space flight hardware and software, and for its integration with the elements from international partners into a fully functional and operating space station.

Named associate administrator for the Space Operations Directorate in 2005, Gerstenmaier directed the safe completion of the last 21 Space Shuttle missions that witnessed assembly completion of the International Space Station. During this time, he provided programmatic direction for the integration and operation of the ISS, space communications, and space launch vehicles.

Gerstenmaier received a Bachelor of Science in aeronautical engineering from Purdue University in 1977 and a Master of Science degree in mechanical engineering from the University of Toledo in 1981. He completed course work early in his career for a doctorate in dynamics and control with emphasis in propulsion at Purdue University, and in spring 2019, he will receive an honorary doctorate from his alma mater.

For his technical contributions and leadership in national and international human spaceflight programs, Gerstenmaier was elected into the 2018 class of the National Academy of Engineering.

Gerstenmaier is the recipient of numerous awards, including three NASA Certificates of Commendation, two NASA Exceptional Service Medals, a Senior NASA Outstanding Leadership Medal, the Meritorious Executive Presidential Rank Award, and Distinguish Executive Presidential Rank Award. He also was honored with an Outstanding Aerospace Engineer Award from Purdue University. Additionally, he was twice honored by Aviation Week and Space Technology for outstanding achievement in the field of space. His other awards include: the AIAA International Cooperation Award; the National Space Club Astronautics Engineer Award; National Space Club Von Braun Award; the Federation of Galaxy Explorers Space Leadership Award; AIAA International Award; the AIAA Fellow; Purdue University Distinguished Alumni Award; and honored at Purdue as an Old Master in the Old Masters Program; recipient of the Rotary National Award for Space Achievement's National Space Trophy; Space Transportation Leadership Award; the AIAA von Braun Award for Excellence in Space Program Management; and the AIAA von Karman Lectureship in Astronautics.

He is married to the former Marsha Ann Johnson. They have two children.

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Mark N. Sirangelo has a long history in space and aerospace having lead program teams that participated in over 300 space missions, including over 20 planetary missions and 70 NASA missions. His recent work experience has been as Scholar in Residence for Engineering, Applied Science and Aerospace at the University of Colorado. Formerly, he was the head of Sierra Nevada Corporation's Space Systems and CEO of SpaceDev, its predecessor company. He also served on the Defense Innovation Board for the Secretary of Defense and as the Chief Innovation Officer of the State of Colorado.

His personal and organizational recognitions include being inducted into the Space Foundation's Technology Hall of Fame, being an Associate Fellow of the American Institute of Aeronautics and Astronautics, named as one of the World's Top 10 Innovative Space Companies by Fast Company, and recognized as Manufacturer Builder of the Year by ColoradoBiz, The Best Place to Work by the Business Journals, and part of Inc. Magazine's top 200 companies. Mr. Sirangelo was a founding member of the Commercial Spaceflight Federation and the founder and Chairman of eSpace, the Center for Space Entrepreneurship. He has been working to make the world a safer place for children as a foundational Board member of the National Center for Missing and Exploited Children. He holds Doctorate, MBA and Bachelor of Science degrees, is a long-term licensed pilot, and has served his country proudly as a U.S. Army officer.