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Statement of

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Mr. Chairman and Members of the Committee, I am very pleased to appear before you today. NASA is proud to be at the forefront of a global effort to advance humanity's future in space, leading the world while expanding on our Nation's great capacity for exploration and innovation. This is a role the Agency has played for over 60 years, leveraging the talent and hard work of America's skilled Government and aerospace industry workforce to push the boundaries of science, exploration, and technology development to achieve bold goals in the aviation and space arenas. Now, pursuant to Space Policy Directive-1 (and consistent with the NASA Transition Authorization Act of 2017), NASA is pursuing "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." We are working on a sustainable campaign of exploration, transitioning the International Space Station (ISS), returning humans to the surface of the Moon and lunar orbit, where we will build the systems, deep space infrastructure, and operational capabilities to expand human presence beyond the Earth-Moon system, eventually embarking on human missions to Mars and other destinations.

Since its inception, NASA's historic and enduring purpose has been aligned to four major strategic thrusts – *Discover, Explore, Develop, and Enable*. These correspond to our missions of scientific discovery of the natural phenomena of the Earth, of other worlds, and of the cosmos as a whole. We conduct missions of exploration in our solar system with humans and robotic probes that expand the frontiers of the human experience, and missions of development that advance new technologies in aeronautics and space systems. NASA leads these missions in collaboration with international and commercial partners. Our long history of international collaboration is a strength that allows us to go farther and faster, while also strengthening international relationships and U.S. standing in the world.

NASA has maintained continuity of purpose over time by serving the American public and supporting a number of national priorities, whose relative emphasis, specific focus, and context have changed over time:

- U.S. Leadership and Inspiration
- Global Engagement and Diplomacy
- Interactions with the Nation's Security and Industrial Base
- Economic Development and Growth
- Addressing Societal Challenges

- Fostering New Discoveries and Expanding Human Knowledge
- Expanding Human Presence in Space

The President's budget request for Fiscal Year 2020 specifically highlights the criticality of partnerships – commercial, international and academic – in maintaining U.S. leadership in space exploration. Partnerships will play a key role in the human exploration of deep space. While we must maintain American leadership in science, technology and human exploration, the involvement of international partners will remain a major part of NASA's exploration plans. Continued collaboration with partners on ISS will be critical to U.S. efforts to use ISS to inform exploration strategies and to help enable lunar exploration and a follow-on presence in low-Earth orbit (LEO). International collaboration will also be a critical element for the Lunar Gateway, as well as lunar and Martian system assets (reconnaissance, human orbital, and human surface). A key part of our overall National Exploration Campaign strategy is to incentivize better cost performance in developing space systems, and where appropriate, share the cost burden of the overall effort through international, commercial and academic partnerships. A sustainable effort will only be possible with smart leveraging of resources and an affordable path forward. NASA will leverage partnerships with the rapidly advancing commercial sector and international community to lay the foundation for a future of unlimited opportunity, discovery and growth.

Exploration Campaign

The Exploration Campaign builds on over 18 years of Americans and our international ISS Partners – Canada, Europe, Japan, and Russia – living and working continuously on the ISS. It leverages the advances made in commercial launch vehicle capabilities, robotics, and other technologies, and accelerates in the next few years with the launch of the Orion capsule and Space Launch System (SLS) rocket which will expand human exploration to cislunar space and the surface of the Moon. The Campaign expands human and robotic exploration in space by: 1) transitioning LEO capabilities to viable and stable industry partners, and 2) pursuing a cislunar strategy that establishes U.S. preeminence to, around, and on the Moon. Beyond this, we 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. We will expand beyond the ISS partners to lead a broad effort across the strategic areas that encompass human spaceflight, science, and technology interests.

Activities across these 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 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.

In carrying out this Campaign, NASA will act as architect, mission leader, and in several key areas, systems integrator, in defining an open architecture that meets national objectives while actively seeking partnerships. The Exploration Campaign will draw upon a variety of innovative partnerships with U.S. commercial industry, other Government agencies, academia, and international partners to meet these objectives. We have designed the Campaign to enable early successes, relying on seamless collaboration across the Agency, and the rapidly advancing capabilities of our commercial partners.

As part of the Campaign, we will also 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. Through an innovative combination of missions involving commercial

and international partners, robotic lunar surface missions will begin as early as 2020, focus on scientific exploration of resources, and prepare for a sustained human presence. Ultimately, these efforts will culminate in the safe landing of U.S. astronauts on the Moon in the late 2020s and establish a sustainable human presence.

Transitioning LEO

NASA will continue its mission in LEO with the ISS to enable exploration with humans to the Moon and on to Mars, while continuing to perform research that benefits humanity, supporting National Laboratory research by private industry and other organizations, and working towards reducing operations and maintenance costs. NASA will continue leading the international partnership that forms the basis of human spaceflight continuity and will leverage and expand beyond the ISS Partnership for the next steps beyond LEO. The Partnership is also being leveraged to define exploration standards that will allow commercial as well as international partnership in the exploration architecture. NASA will continue to leverage its resources and capabilities to enable the development of a commercial market in LEO and alternatives to a Government-directed human spaceflight infrastructure in LEO.

Under the auspices of the ISS National Laboratory, managed by the Center for the Advancement of Science in Space (CASIS), NASA and CASIS continue to expand research on the ISS sponsored by pharmaceutical, technology, consumer product, and other industries, as well as by other Government agencies, such as the National Institutes of Health and the National Science Foundation. Through CASIS' efforts, the ISS National Lab has reached full capacity for allocated crew time and upmass and downmass. NASA also works with commercial companies, such as NanoRacks, to support commercial activity on the ISS.

NASA intends to transition from the current Government-dominated model of human spaceflight activities in LEO to a model where Government is only one customer for commercial services. The Agency is increasing the breadth and depth of commercial and international LEO activities. NASA will expand partnerships in LEO to include new companies and other nations beyond the ISS Partners, including working with commercial partners to support visiting crew. Based on inputs from international, Government and commercial stakeholders, NASA will begin this year to take steps that will enable the transition from direct Government funding of ISS to the use of commercial services and partnerships by 2025. The plan will feature new, independent commercial platforms or a non-NASA operating model for some form or elements of the ISS, or both. In addition, NASA will expand public-private partnerships to develop and demonstrate technologies and capabilities to enable new commercial space products and services.

SLS, Orion and Exploration Ground Systems

NASA is building a deep space launch and crew system – the Orion spacecraft, the heavy-lift SLS launch vehicle, and the supporting Exploration Ground Systems (EGS) – to support the Exploration Campaign. The SLS Block 1 will be capable of delivering Orion to cislunar space by the early 2020s and will play a critical role in delivering crew to the Lunar Gateway. While upgrading the SLS to the Block 1B configuration remains an important future capability, recent performance issues and delays in SLS core stage manufacturing and design updates related to the Exploration Upper Stage requirements, require that NASA concentrate in the near term on the successful completion of Exploration Mission-1 (EM-1) and EM-2, and supporting a reliable annual SLS and Orion flight cadence thereafter. As a result, SLS Block 1B final development efforts will be deferred to later exploration missions. The Orion crew vehicle will carry up to four humans to deep space for up to 21 days, and when combined with additional habitation can support longer-duration missions.

The first SLS/Orion mission will be the uncrewed EM-1, followed by the first crewed SLS/Orion mission, EM-2. The EM-1 and EM-2 launch dates are under review pending completion of independent assessments of core stage production and the integrated mission schedule. These SLS/Orion missions will demonstrate the capability to operate safely and productively around the Moon. SLS, Orion, and EGS are the critical capabilities for maintaining and extending U.S. human spaceflight leadership beyond LEO to the Moon, Mars, and beyond.

Lunar Gateway

As a key part of the Exploration Campaign, NASA will establish the Lunar Gateway, a way station that will orbit the Moon and enable human and robotic missions to the lunar surface. The Lunar Gateway will support exploration on and around the Moon, and sustainable human lunar surface exploration missions by supporting reusable human lunar landers. It will be a temporary home for astronauts and will foster growing domestic and international economic opportunities for commercial logistics and refueling services as well as provide robust communications with spacecraft in cislunar space and on the lunar surface. The Lunar Gateway will allow for a continuously expanding knowledge base in the area of deep space maneuvering and solar electric propulsion (SEP). Through the development of Lunar Gateway, the U.S. will maintain in leadership in space exploration and discovery as it pioneers a new era of space travel research, logistics, and economic developments.

The Lunar Gateway will be assembled in orbit around the Moon where it will be used immediately as a staging point for missions to the lunar surface. The initial functionality will support lunar landers and requires two main functions: A Power and Propulsion Element (PPE) and habitation. These functions will provide critical abilities for the Lunar Gateway to support human-class reusable landers, landing a crew of up to four astronauts on the lunar surface and ultimately developing sustaining lunar operations on the Moon. Gateway is evolvable and supports early reusable lunar surface capability and later more complex lunar science and Mars exploration technology development.

From a strategic perspective, the Lunar Gateway takes advantage of existing ISS partnerships with private companies and the international community from LEO to the Moon. The ISS international partnership on 5 March 2019 signed a joint statement that commits the ISS space agencies to evaluate their potential contributions to the Gateway. It will give us a strategic presence in cislunar space that will enable sustainable exploration of the Moon and its resources and leverage that experience for eventual human missions to Mars. The Lunar Gateway provides access to a variety of lunar surface destinations that scientific investigations have found worthy of direct human inspection and exploration. Opportunities for U.S. commercial and international partners could range from the supply of utilization payloads and logistics, to the provision of entire modules of the Lunar Gateway. International partnerships have been a vital component of space exploration, allowing countries to advance national objectives while working together to achieve greater and more collaborative goals. Following the commercial model that NASA pioneered in LEO for space station resupply, NASA plans to launch Lunar Gateway elements and resupply it through competitively-procured commercial cargo missions and internationally-contributed cargo missions. Commercial spacecraft could also dock to the Lunar Gateway between crewed missions to conduct other activities. Additional potential exists for future commercial spacecraft to transport crew to visit the Lunar Gateway. The Lunar Gateway will be designed with standard interfaces, encouraging all partners to leverage its capabilities and improve competition for the benefit of space exploration. These strategies will be essential toward establishing a sustainable and resilient Exploration Campaign. Subsequent cost savings will enable NASA to redirect funding towards in-space and lunar surface activities.

While NASA will remain the overall lead as Lunar Gateway architect, systems integrator, and operator, the Lunar Gateway team has been studying various implementation approaches to identify U.S.

commercial and international contributions to the Lunar Gateway architecture. The U.S. commercial efforts include design concepts initiated under the Next Space Technologies for Exploration Partnerships (NextSTEP) habitation development activity and international concepts have been initially identified through architecture studies with the ISS partners.

Prime Minister of Canada Justin Trudeau formally announced on February 28, 2019 Canada's intention to join NASA in U.S.-led exploration at the Lunar Gateway and the lunar surface, the first international partner to do so. In accordance with a joint statement signed by all partners on 5 March 2019, additional commitments are expected by the end of the year, with ultimate participation by all existing ISS Partners. NASA is currently conducting architecture studies to evaluate all options for accelerating human lunar return, including potential international contributions. The results of these studies may lead to international contributions focused on lunar surface exploration prior to Gateway expansion beyond an initial few (2-3) modules.

While additional international contributions to enable sustainable lunar surface exploration are examined, potential Lunar Gateway contributions currently include:

- Upon approval by its Member States, the European Space Agency (ESA)'s provision of the European System Providing Refueling Infrastructure and Telecommunications (ESPRIT) module with a science airlock including additional propellant storage and advanced lunar telecommunications capabilities;
- European development of a Lunar Gateway habitation module with significant contributions from the Japan Aerospace Exploration Agency (JAXA);
- Russia's expressed interest in developing and contributing a multi-purpose module, which would also include airlock functionality and redundant human transportation capability; and
- Logistics Modules delivered to the Lunar Gateway by both U.S. and international partners, the cadence of which would be driven by mission needs.

Lunar Landers and Robotic Missions

Our goal is not just to leave footsteps and plant flags but to learn how to live away from Earth. Working with our commercial and international partners, we will establish a foundation for ongoing human exploration of our nearest celestial neighbor. Following a buildup of capabilities, our goal is to land astronauts on the Moon within the next decade. Astronauts will explore the surface for increasing periods of time while developing the experience and technology we need for future missions to Mars and other destinations.

NASA will work with American companies through Broad Agency Announcement (BAA) awards and funded Space Act Agreements (SAAs) to design and develop new reusable systems for astronauts to land on the lunar surface. The Agency is asking American companies to study the best approach to landing astronauts on the Moon and start the development as quickly as possible with current and future anticipated technologies. NASA is planning a series of lunar lander demonstration missions with the first uncrewed mission testing human descent capabilities on the surface in 2024. Early commercial delivery missions to the Moon will test technologies, and demonstrate capabilities that will help improve designs for landers to carry astronauts. These missions, coupled with early uncrewed descent demonstration missions, will once again help NASA gain real-world experience to land astronauts on the Moon.

Science remains critical to the exploration goals of the Agency, contributing both capabilities and knowledge needed to advance human and robotic exploration of the Moon, Mars, and beyond. The Lunar Discovery and Exploration program advances an integrated strategy for exploration, not only through

improved collaboration across the Agency but also by leveraging interagency, international, and commercial partnerships. In November 2018, NASA selected nine U.S. companies to bid on delivery services to the lunar surface through Commercial Lunar Payload Services (CLPS) contracts. Lunar payloads from a variety of customers, including NASA, will fly on contracted missions starting in 2020, enabling critical technology demonstrations and scientific observations; most recently, NASA selected 10 proposals for the Development and Advancement of Lunar Instrumentation (DALI) program, which will support instruments that will fly on future lunar missions. NASA's Lunar Reconnaissance Orbiter (LRO), which marks its tenth anniversary in 2019, continues to help scientists characterize the lunar surface, providing insights into lunar resource analysis that could support future human exploration.

NASA's lunar efforts will incorporate results from the following:

- The Lunar Cargo Transportation and Landing by Soft Touchdown (CATALYST) initiative, established in 2014, is encouraging the development of U.S. private-sector robotic lunar landers capable of successfully delivering payloads to the lunar surface using U.S. commercial launch capabilities.

- NASA issued a solicitation on February 7, 2019 to seek proposals from industry for human lander system studies, risk reduction, development, and spaceflight demonstrations. These NextSTEP partnerships will enable rapid development and flight demonstrations of human lunar landers by supporting critical studies and risk reduction activities, maturing requirements, tailoring applicable standards, and creating technology maturation plans.

- NASA and its industrial partners are also working on NextSTEP habitation systems to develop concepts for cislunar habitats and to conduct ground-based testing of prototype habitats to evaluate human factors, validate subsystem integration, and test standard interfaces. The knowledge gained from testing the NextSTEP habitats will reduce risk in the design of the Lunar Gateway.

Missions to the Moon and cislunar space will also 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.

Exploration Technology

NASA's Exploration Technology will accelerate technology development to enable human and robotic exploration of the Moon and Mars and foster commercial expansion in LEO and beyond. Technology drives exploration with investments spanning the Technology Readiness Level (TRL) spectrum, advancing early-stage concepts and maturing key technologies and systems that enable demonstrations in relevant environments.

Within Exploration Technology, NASA will accelerate development of lunar surface technologies through the Lunar Surface Innovation Initiative, driving essential technologies required for humans to successfully operate on the lunar surface:

- NASA is developing the technologies to make use of resources available on the Moon, on Mars, and on other planetary bodies (*in situ* resources). This technology holds the potential to produce consumables, including oxygen, water, and hydrogen on the Moon, thus drastically reducing mission mass, cost, and risk for human exploration.

- In order to address power requirements for long-duration human missions on the Moon, NASA is continuing work on its Kilopower technology project to demonstrate a small, lightweight fission power system. The Kilopower project will transition into a demonstration mission in FY 2020 that would permit long-duration crewed missions on the surface of the Moon.

The Lunar Surface Innovation Initiative will bring together the full range of stakeholders, including entrepreneurs, academia, small businesses, industry, and the NASA workforce to catalyze technology and systems development.

On to Mars

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.

NASA will advance robotic access to Mars in preparation for human exploration. The Agency will:

- Continue the search for life with a Mars rover in 2020;
- Demonstrate technology to produce oxygen from Mars resources, critical for future human Mars missions;
- Begin planning a first-ever sample-return Mars mission;
- Appropriately prioritize and guide investments and partnerships in long-pole technology areas and resource characterization needed for deep-space exploration; and
- Develop standards for human long-duration deep space transportation vehicles.

Working with science and human exploration communities, our international partners, and U.S. industry, NASA will refine the goals and objectives for a robust lunar exploration and science program.

Partnerships

In implementing its human exploration plans, NASA will work to make best use of the tools available for partnership opportunities so the Agency can leverage the knowledge, skills, and resources of potential commercial, academic, and international partners. In the public-private partnership arena, NASA will consider a variety of mechanisms from university grants, to SAAs (which may be funded or unfunded), to Federal Acquisition Regulation-based contracts. The use of SAAs and contracts has played a key role in the operation of ISS, and NASA anticipates using the flexibility of different types of partnership to best effect as the Agency proceeds with human missions into deep space. Similarly, in the international arena, the ISS partnership, for example, has enabled construction and operation of a space station that benefits from the support of dedicated aerospace professionals around the world. Significant international collaboration is also occurring at the Moon and Mars, bringing benefit to the whole of the exploration endeavor.

International partnerships have been a vital component of space exploration. When nations develop indigenous technologies, systems, and missions to further domestic objectives, they contribute to the aggregated advancement of capabilities that enable greater and more collaborative goals. The success of the ISS is a testament to the viability of a long-term, multi-national technology and exploration partnership, which will remain a key aspect of human exploration further into the solar system.

NASA's strategy for leading global collaboration, based on mutually beneficial international and commercial partnerships, will leverage successful ISS and other NASA partnerships and build new

cooperative exploration ventures to develop spaceflight capabilities. This strategy will take into account risks, challenges, and rewards posed by relying on partners for critical capabilities and technologies.

NASA is also coordinating exploration planning with external organizations: the Lunar Exploration Analysis Group, Mars Exploration Program Analysis Group (MEPAG), International Space Exploration Coordination Group, International Mars Exploration Working Group (IMEWG), National Academy of Sciences decadal surveys, etc. Through these partnerships, the expansion of humans beyond LEO can be achieved faster and in a more cost effective manner.

Similarly, NASA is working with its international partners to advance human and robotic exploration on and around the Moon. Last year, I chaired a meeting of senior leaders from space agencies around the world in conjunction with the International Astronautical Congress in Bremen, Germany. Following this exchange of ideas, NASA is working to identify partnership opportunities that widen the pool of resources, enhance sustainability, and advance our most important exploration objectives. I look forward to convening similar multilateral discussions this year.

Conclusion

One of the Agency's key goals is opening the space frontier with the objective of extending human presence deeper into the solar system starting with returning humans to the Moon through a sustainable human and robotic spaceflight program. The Agency has developed a strategic, pioneering approach to expand the distance and duration of human space exploration, building off the research happening today on the ISS. As NASA continues to develop an acquisition strategy for the Exploration Campaign, we will identify new sources for critical technologies in the U.S. private sector and Government, and international partners. NASA will demonstrate and enhance U.S. leadership in space by collaborating with international counterparts on mutually beneficial goals. The Agency believes this human exploration infrastructure can be achieved and sustained with the national funding commitment laid out in the President's Budget request. Key to our success will be reforming our programs to be more cost effective and to successfully achieve the objectives laid out through new business models and partnerships. Space exploration, at sustainable funding levels and supported with domestic and international capabilities and collaborations, is a long-term endeavor. NASA is pushing human presence deeper into space while making new discoveries and strengthening the Nation's diplomatic posture. We appreciate the Committee's continued support, and I would be pleased to respond to your questions.