National Aeronautics and
Space Administration

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Presented by Witnesses

February 9, 2022

Subcommittee on Space and Science
Committee on Commerce, Science, and Transportation

United States Senate

Statement by:

James Free, Associate Administrator, Exploration Systems Development Mission Directorate
Thomas Zurbuchen, Associate Administrator, Science Mission Directorate
James Reuter, Associate Administrator, Space Technology Mission Directorate

117th Congress

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Introduction – the New Space Environment

Sixty years ago, President John F. Kennedy charged NASA with landing a human on the surface of the Moon. At the time, only the United States and the Soviet Union had significant national space programs, and commercial companies involved in space were primarily Government contractors. Today, both the international and commercial space landscape look very different. The U.S. Government's investment in space exploration has enabled a new era of commercial investment in space activities. Encompassing everything from satellite-based communications and navigation applications to commercial launch, the economic output of the U.S. commercial space sector is now estimated in the hundreds of billions of dollars. Last year saw another big first of the commercial space industry, with the first civilian crews launching to space. The launch of civilian crews by private companies, in addition to other commercial space activities, is evidence that the original investment by taxpayers in NASA has been leveraged to create thousands of private sector jobs in the rapidly growing space enterprise.

The development of a robust commercial space industry is partially the result of decades of policy direction from the U.S. Congress. In 1990, Congress amended the National Aeronautics and Space Act, directing NASA to "seek and encourage, to the maximum extent possible, the fullest commercial use of space" and "encourage and provide for Federal Government use of commercially provided space services and hardware" (Title 51 U.S.C. 20112). Today, NASA's commercial partnerships span human exploration, space science, technology development, and aeronautics. We are pleased to appear before the Committee today to give you an update on how these partnerships help NASA achieve its objectives.

Human Spaceflight

Partnerships in Low-Earth Orbit (LEO)

The NASA Authorization Act of 2008 (P.L. 110-422) noted that "…a healthy and robust commercial sector can make significant contributions to the successful conduct of NASA's space exploration program" and that there were many activities:

> "…such as routine supply of water, fuel, and other consumables to low Earth orbit or to destinations beyond low Earth orbit, and provision of power or communications services to lunar outposts, that potentially could be carried out effectively and efficiently by the commercial sector at some point in the future. Congress encourages NASA to look for such service opportunities and, to the maximum extent practicable, make use of the commercial sector to provide those services."

Following this direction, NASA invested in developing new commercial space transportation, and today purchases services from U.S. companies for the resupply of the International Space Station (ISS) and for crew transportation services. Fourteen U.S. and partner astronauts have now flown to ISS on SpaceX's Crew Dragon. These commercial flights are licensed for launch and reentry by the Federal Aviation Administration, but were developed and are operated in close collaboration with NASA to ensure safety for the crew. NASA is now laying the groundwork for future commercial space stations through the Commercial LEO Destinations (CLDs) program. NASA will enable the development of commercially-owned and -operated LEO destinations that are safe, reliable, and cost-effective. It is NASA's goal to be one of many customers of CLD services, purchasing only the goods and services the Agency needs. CLDs, along with commercial crew and cargo transportation, will provide the backbone of the human LEO ecosystem after the ISS retires.

There are already over 20 commercial facilities operating aboard ISS today – including a 3D printer, a bioprinter, external Earth observation and materials platforms, and an airlock – that are available for use by both NASA and other paying customers. The ISS is now entering an era of robust commercial use as we prepare the way for CLDs. In order to prevent a gap in U.S. presence in LEO, the Administration extended use of the ISS through 2030 to ensure CLDs are online before retirement of the ISS.

It is NASA's goal to continue international partnerships in LEO, beyond the life of the ISS. Each ISS Partner is currently working to identify its needs in LEO through and beyond the ISS, and all have expressed interest in the expansion of commercial uses of LEO. It is NASA's intention to ensure continued collaboration with international partners on a U.S. CLD through government-to-government, government-to-industry, and/or industry-to-industry arrangements.

Artemis and Deep Space Exploration

Pursuing the Nation's goals beyond LEO, NASA continues to make progress on America's next great exploration initiative: Artemis. The Artemis generation of moonwalkers will be selected from a diverse astronaut corps and will include the first woman and the first person of color on the Moon. In the next few months, NASA will launch Artemis I. Artemis will feature the Space Launch System (SLS) - the most powerful rocket NASA has ever built; the Orion spacecraft, capable of carrying four astronauts to deep space; and Exploration Ground Systems (EGS), which develops and operates the ground systems and software needed to launch and operate the rocket and spacecraft. Along with the Human Landing System (HLS) now undergoing development, these systems will carry humans farther into space and for longer durations than ever before. Soon the entire vehicle will be rolled out to the pad for wet dress rehearsal in preparation for the Artemis I mission.

Following this year's uncrewed Artemis I flight test, NASA will conduct Artemis II, a crewed flight test around the Moon in Spring of 2024. After these test flights, NASA will launch Artemis III, which will return U.S. astronauts to the surface of the Moon in 2025 or soon thereafter.

On the Artemis III mission, two of the four astronauts will board the HLS from Orion for their descent to the lunar South Pole while the other two crew remain inside Orion in lunar orbit. Last year, NASA selected SpaceX to build a Starship lunar lander for this mission through a contract award that includes one uncrewed and one crewed demonstration mission. To achieve landings beyond Artemis III, NASA intends to initiate a competitive, fixed-price, milestone-based procurement for crewed lunar surface transportation services that will provide human access to the lunar surface on a recurring basis beyond the initial crewed demonstration mission.

NASA is also developing Gateway, a lunar outpost that will serve as an orbital platform supporting future human and robotic missions to the lunar surface. Gateway will also support science research and technology efforts from its unique, deep space orbital vantage point. Development and production of the Gateway's first two components—the Power and Propulsion Element and the Habitation and Logistics Outpost—are under development and aiming for a launch date in 2024. These initial Gateway elements will be launched together, and the Power and Propulsion Element will push them to lunar orbit where they will begin operating science instruments and prepare to provide critical support in human-class lander deployments and operations enabling

lunar surface activities. Gateway is also a demonstration of NASA's continued commitment to international cooperation through Artemis. NASA will extend and expand its international partnerships from low-Earth orbit to Gateway and will continue to do so on the surface of the Moon. Artemis will present new opportunities to deepen and broaden international collaboration.

Astronauts working on and exploring the surface of the Moon will need a new generation of spacesuits and rovers to enable capabilities that go beyond what was accomplished in the Apollo era. NASA has begun to work with the commercial space industry to develop new spacesuits while continuing to leverage the Agency's expertise on spacewalk systems, spacesuits and operational concepts. The NASA workforce remains critical to the success of future spacesuit programs and will provide data and insights from NASA designs and development to companies for use in their own concepts. NASA is also working with U.S. industry to refine requirements and develop concepts for rover vehicles that would greatly extend surface exploration range for Artemis V and beyond.

Building upon the work done during Apollo, as well as recent and future robotic lunar missions, NASA intends to make this exploration effort a sustained one with help of new technologies as well as innovative commercial and international partnerships, all while advancing principles for peaceful and sustainable space exploration through the Artemis Accords.

Planning for the Artemis missions is ongoing and includes cross-program technical integration to ensure alignment of requirements and interfaces across the multiple systems and contracts relevant to Artemis. It also encompasses program performance, data delivery requirements to support integration products, budget planning, schedule management, risk tracking, and configuration and audit management.

Make-Buy Decisions

In accordance with its procedural requirements and policy directives, NASA examines cost, risk (cost, schedule, technical and safety), technical maturity, commercialization goals, vendor/contractor accountability and mission risks when deciding to make, build or buy exploration goods and services. Long-standing national policy requires NASA and other Federal agencies to "purchase and use United States commercial space capabilities and services, to the maximum practical extent under existing law, when such capabilities and services meet United States Government requirements."[1] NASA evaluates the maturity of the marketplace as well as in-house capabilities that provide or could provide a good or service. The Agency considers whether to acquire the capability in house, where doing so is in the national interest and does not compete with United States commercial space activities, to acquire it from outside the Agency, or to acquire it through some combination of the two approaches. A trades analysis of the options based on the factors described above aids the make or buy determination. In all procurement cases, NASA develops contractor oversight and insight plans to ensure crew safety and maximize mission success.

Space Technology

NASA's Space Technology Mission Directorate (STMD) supports the development of a broad scope of transformative technologies addressing multiple stakeholder needs while enabling NASA's future missions to the Moon, Mars, and beyond. Investments in space technology drive new capabilities through technology demonstrations, prize competitions, and partnerships that fuel solutions to complex challenges needed to fulfill the Agency's and the Nation's goals in space.

Technology development takes time to move from idea to integration into a mission, and NASA is seeing tremendous results coming out of the sustained investments in technology over the past decade. NASA's Perseverance rover landed safely on Mars thanks to many Entry, Descent, and Landing systems working in harmony, including real-time, autonomous visual mapping technology provided by STMD's Terrain-Relative Navigation (TRN) technology. Along with TRN, NASA also delivered the Mars Oxygen In-Situ Resource

[1] National Space Policy of the United States of America, December 9, 2020, https://trumpwhitehouse.archives.gov/wp-content/uploads/2020/12/National-Space-Policy.pdf.

Utilization Experiment (MOXIE) to Mars to demonstrate a new, critical capability: producing oxygen directly from the carbon-dioxide-rich atmosphere – which is needed for future astronauts to breathe and as potential rocket propellent. As of January 2022, MOXIE had completed eight runs and produced the equivalent of 105 minutes of breathable oxygen for an astronaut. The Laser Communications Relay Demonstration (LCRD) moved closer toward its culminating demonstrations with a launch in December 2021, followed by a successful check out. LCRD recently demonstrated its first optical communication with ground stations, a key milestone toward realizing high-speed data rates for our missions.

In the coming months, NASA will send the Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) spacecraft to the Moon to help reduce risk for future spacecraft by validating innovative navigation technologies and verifying the dynamics of its halo-shaped orbit. Technologies NASA looks forward to demonstrating in this decade include high-performance spaceflight computing, Deep Space Optical Communications, and high-power solar-electric propulsion. Some of the challenges that NASA is focused on addressing moving forward include dust mitigation, excavation, construction, extreme access/environments, and in-space manufacturing and assembly.

STMD has leaned forward on partnerships focused on industry-developed space technologies that can advance the commercial space sector and benefit future NASA missions. Through its Tipping Point solicitations and Announcement of Collaborative Opportunities, STMD makes joint investments with industry to conduct ground and/or flight demonstrations that result in a significant advancement of the technology's maturation, and a significant improvement in the partners' ability to successfully bring the technology to market. STMD is planning to announce its next Tipping Point awards later this month, which for the first time will feature funded Space Act Agreements.

NASA has learned that by forging direct partnerships with companies and other Government agencies, it can leverage expertise and common interest to better maximize the investment Congress and the taxpayers have entrusted us with. To that end, STMD will continue to pursue partnerships for technology payload demonstrations to bring about new on-orbit assembly and manufacturing technologies, including On-orbit Servicing, Assembly, and Manufacturing-1 (OSAM-1) a robotic spacecraft equipped with the tools, technologies, and techniques needed to extend satellites' lifespans – even if they were not designed to be serviced on orbit – and OSAM- 2, which partners with Redwire to build, assemble, and deploy its own operational solar array. STMD is also using partnerships to advance cryogenic fluid management, an integral part of exploration systems for Earth-to-Orbit Transportation, long term storage in space, In-Situ Resource Utilization (ISRU), tanks and feed systems for lunar landers, and enabling rapid transit propulsion to Mars, such as nuclear propulsion. Through these efforts, the Directorate qualifies critical technologies that can be transferred to U.S. industry and meet multiagency needs.

To champion technologies needed for Artemis, including living on and exploring the Moon, STMD established the Lunar Surface Innovation Initiative (LSII). Through this initiative, NASA pursues development of lunar surface technologies, including surface power, ISRU, extreme access, excavation and construction, dust mitigation, and cross-cutting systems to support operations in extreme environments, ultimately resulting in long-duration testing in simulated lunar and Martian environments. Surface power is a pressing need to enable lunar surface missions. NASA, in coordination with the Department of Energy, issued a joint solicitation in November 2021 asking American companies for design concepts for a fission surface power system that could be ready to launch within a decade for a demonstration on the Moon. LSII has also awarded over $200 million through STMD Programs to establish collaborations across industry and academia. The Johns Hopkins Applied Physics Laboratory (APL) continues to operate the Lunar Surface Innovation Consortium (LSIC), convening monthly focus groups and hosting workshops focused on lunar surface technology development. LSIC has over 1,500 participants from over 600 organizations representing industry, academia, other Government agencies, and nonprofits from all 50 states and 38 countries.

The Agency's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs give NASA access to innovations from a diverse group of entrepreneurs with different backgrounds and perspectives so they may contribute to NASA's efforts in human exploration, space technology, science, and

aeronautics. NASA SBIR/STTR invested more than $201 million in small businesses and research institutions in FY 2021. Specifically, 305 SBIR and 56 STTR Phase I contracts were awarded to 287 U.S. small business teams to establish the scientific, technical, and commercial feasibility of each proposed innovation. Additionally, the program made 142 SBIR and 22 STTR Phase II awards to further expand upon prior Phase I work.

NASA's technology portfolio contains many innovations that not only enable science and exploration but also address challenges and improve life here on Earth. The Agency's Technology Transfer program within STMD offers several resources for potential licensees in industry and academia. This program demonstrates NASA's commitment to finding the widest possible applications for NASA technology through partnerships and licensing agreements with industry, ensuring that NASA's investments in its missions and research find additional applications that benefit the Nation and the world.

Science

Commercial Partnerships

NASA's Science Mission Directorate (SMD) has worked hard to engage with commercial partners to understand what is possible now and to support innovations for the future. Over the last several years, SMD has been experimenting with commercial partnerships to understand what works and what does not, continually examining the number and type of commercial partnerships based on science needs and innovations within the commercial sector. Decisions about whether to partner are focused on obtaining the "most science per dollar" and whether NASA can be an early customer in an area that shows promise to develop into a new business segment.

For example, the Commercial Lunar Payload Services (CLPS) initiative is leveraging the innovation of America's aerospace industry to deliver dozens of NASA payloads quickly and affordably to the lunar surface, with the goal of eventually being one of many customers. The Agency has the advantage of being able to ask these companies to move quickly and take risks that will benefit science as NASA pursues a NASA-wide Moon to Mars program.

NASA is also experimenting with novel partnerships across the Government and with companies by standing up a Rideshare Office to allow more science to fly on the major missions the Agency launches and undertaking commercial data purchases from smaller Earth observation companies to augment NASA's capabilities and take advantage of what new market players have to offer. Throughout this process of increasing commercial partnerships, SMD has been willing to take on more risk in the interest of establishing high-value U.S. capabilities in space.

Use of NASA Data to Improve Life on Earth

NASA's Earth Science Division partners with the non-profit and commercial sectors to advance Earth system science and enable scalable societal benefits. Partnerships with conservation and humanitarian organizations (e.g., Conservation International, Mercy Corps) provide NASA data to support climate-smart agriculture and to assist river basin managers who must deliver water supplies in the face of a changing climate. The NASA Harvest Consortium works with the Agency's partners in the public and private sector to support global food supply decisions in food security and agricultural markets, providing independent information and transparency to global commodity markets. With technology and software partners like Microsoft, NASA combines its vast data and technology resources to help build resilient cities by improving the understanding of the impacts of urban heat and poor air quality on vulnerable communities across the United States.

NASA's premier Earth Science data resources will increase dramatically over the next decade through the Agency's science missions and through Earth observation data buys. SMD plans to expand these data buys to allow sharing with non-NASA users, thereby increasing the usefulness of the data. These commercial data, when combined with cloud-based systems and artificial intelligence and machine learning tools (AI/ML), already allow scientists to conduct science they could not do with traditional data sources alone. For example, a study from the NASA Goddard Space Flight Center used AI/ML techniques to count isolated trees and shrubs across 1.3 million

square kilometers of the West African Sahara and Sahel regions. They detected over 1.8 billion large trees and shrubs, which are important for biodiversity, carbon storage, and food and shelter for the local communities.

SMD's Planetary Science Division is addressing threats to the Earth of near-Earth objects (NEOs). The Planetary Defense Coordination Office is making steady progress in identifying hazardous NEOs and developing the NEO Surveyor Mission to more thoroughly search for asteroids in space. The Double Asteroid Redirection Test (DART) mission will be humanity's first attempt to deflect the path of an asteroid, testing this method for future mitigation of a hazardous NEO.

Finally, the Heliophysics Division is working to better understand our sun and its effects on Earth's ionosphere – where space weather can impact electronic systems and have the potential to create massive disruptions. The Division works closely with the National Oceanic and Atmospheric Administration, National Science Foundation, and Department of Defense partners to improve prediction of these solar storms.

Mission Management Processes and Teams

Over the last two years, SMD's Large Mission Study, conducted by an independent team of experts, provided an objective look at how the Directorate manages large, strategic science missions. Recommendations from that study included improving cost and schedule planning that includes life cycle costs for discrete project elements, probabilistic cost estimates throughout the project lifetime, setting joint cost and schedule confidence levels, and providing for independent cost estimates, where needed. In addition, the study recommended that standing review boards be a matter of course. SMD has begun implementing the recommendations in the Large Mission Study for its missions in development.

SMD does not exist without the broader scientific and space communities. The past several years have demonstrated the need to build a resilient set of communities that support a true national space program, across university partners, NASA Centers, large and small industry partners, and at the human level. It is all of our work, individually, and together, that enables success across the Directorate and the Agency.

Through partnerships with other scientific institutions and through new, meaningful relationships with diverse audiences, especially underserved populations, SMD seeks to contribute to the advancement of a sustainable scientific enterprise across its many disciplines, building the career and development pathways for the people who will be the future of our national space program.

Building an Inclusive Team

While NASA needs the right processes in place to successfully manage missions, the Agency also needs the right people, and the Agency has worked to advance a culture of diversity, equity, inclusion, and accessibility (DEIA) demonstrating NASA's core values. This work extends across all levels of the organization and is central to its strategic planning and the commitments made to stakeholders and the communities the Agency serves. Building an inclusive team that reflects the diversity of the Nation is mission critical. To that end, NASA has been taking a strategic approach to managing its workforce, strengthening recruitment practices, and creating leadership development and mentoring opportunities to strengthen the organization. It is a continuous learning process that seeks to identify and eradicate the systemic obstacles that impede or dissuade underrepresented groups from joining and rising through NASA's ranks.

Mr. Chairman, we would be happy to respond to any questions you or the other Members of the Subcommittee may have.