HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
September 26, 2018

Statement of

James F. Bridenstine
Administrator
National Aeronautics and Space Administration

before the

Subcommittee on Space, Science, and Competitiveness
Committee on Commerce, Science, and Transportation
United States Senate

Mr. Chairman and Members of the Subcommittee, 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. 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.

Exploration Campaign

The National Space Exploration Campaign builds on 18 years of Americans and our international partners 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.

A key component of establishing the first permanent, 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. Gateway in-space assembly starts with the launch of the power and propulsion element (PPE) no later than 2022 aboard a commercial rocket. Gateway ground testing, risk reduction, and development activities are already underway at NASA centers across the United States, including facilities in Ohio, Texas, Florida, Virginia, and Alabama, as well as in facilities of private sector partners in those states as well as in Colorado and Nevada. Following the successful in-space demonstration of the PPE and the delivery of the first pressurized Gateway modules, U.S. astronauts will be visiting before the end of 2024.

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. Ultimately, these efforts will culminate in the safe landing of U.S. astronauts on the Moon before the end of the 2020s.

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 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 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.

The Exploration Campaign has five strategic goals:

1. Transition U.S. human spaceflight in LEO to commercial operations that support NASA and the needs of an emerging private sector market.

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.

5. Demonstrate the capabilities required for human missions to Mars and other destinations.

NASA will act as architect, mission leader, and in several key areas, systems integrator, defining an open architecture that meets National objectives. The Exploration Campaign will draw upon a variety of innovative partnerships with U.S. commercial industry, other Government agencies, academia, and international partners. We have designed the Exploration Campaign to enable early successes, relying on seamless collaboration across the Agency, including Deep Space Exploration Systems, Exploration Technology, LEO and Spaceflight Operations, and elements of Science, and the rapidly advancing capabilities of our commercial partners. I'll now describe our plans in each major domain of the Campaign – Earth Orbit, the Moon, and Mars – in more detail.

Transitioning LEO

The ISS will continue to serve as a core long-duration human spaceflight asset through at least 2024 – which will mark nearly 25 years of continuous human occupancy. Currently, NASA is leveraging the ISS to learn how to keep crews healthy and productive on deep space missions, and as a testbed to develop technologies to support those missions. The ISS is an experiential testing ground that enables discovery and development of advanced robotics, communications, medicine, agriculture, and environmental science. ISS also provides an example of international collaboration on large space projects. ISS can also enable the transition to commercial companies' use of LEO. NASA recently awarded 12 study contracts

to industry to investigate the best way to use the ISS to enable commercial industry to take a lead role in LEO. The portfolio of selected studies will include specific industry concepts detailing business plans and the viability of habitable platforms, using Station or separate free-flying structures.

Maintaining the ISS and future orbital platforms requires a fleet of vehicles to sustain a constant supply line of both crew and cargo. Under the original Commercial Resupply Services (CRS) contracts, our two commercial cargo partners, Space Exploration Technologies (SpaceX) and Orbital ATK (now Northrop Grumman), are providing cargo deliveries to the ISS. Under the new CRS-2 contracts, SpaceX, Northrop Grumman, and Sierra Nevada Corporation will deliver critical science, research, and technology demonstrations to the ISS over five years from 2020 through 2024. Working with our commercial crew partners, SpaceX and the Boeing Company, NASA plans to return crew launch capability to American soil in 2019.

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 space activities in LEO to a model where Government is only one customer for commercial services. Starting in 2018, the Agency will increase the breadth and depth of commercial and international LEO activities. NASA will expand partnerships in LEO to include new companies and new nations, including working with commercial partners to support new international astronaut visits. Based on inputs from current ISS partners, commercial and other stakeholders, NASA will shape the plan for the transition of LEO activities from direct Government funding to commercial services and partnerships, with new, independent commercial platforms or a non-NASA operating model for some form or elements of the ISS by 2025. In addition, NASA will expand public-private partnerships to develop and demonstrate technologies and capabilities to enable new commercial space products and services.

Lunar Exploration

NASA is building a 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 Orion crew vehicle will carry up to four humans to deep space for up to 21 days. The Orion will also be able to transport and dock co-manifested modules to Gateway, and provide key initial life-support and abort capabilities. The SLS Block 1 cargo variant will be capable of delivering Orion to cislunar space in the early 2020s, and the Block 1B SLS will be capable of delivering 8-10 metric tons co-manifested with Orion in the mid- to late-2020s. The first SLS/Orion mission will be the uncrewed Exploration Mission-1 (EM-1), to be launched to lunar orbit in FY 2020, followed by the first crewed SLS/Orion mission, EM-2, no later than 2023. These SLS/Orion missions will demonstrate the capability to operate safely and productively around the Moon. These are the early steps on a journey that leads American astronauts into deep space, sustainably and permanently.

SLS Core Stage integration and outfitting (including installation of the four RS-25 main engines developed from the Space Shuttle) has continued at Michoud Assembly Facility. EM-1 flight hardware is being delivered to the Kennedy Space Center (KSC). SLS has continued a series of EM-1 Design Certification Reviews, will conduct the Critical Design Review (CDR) for EM-2, and begin fabrication of components for EM-3 and beyond. For EM-1, the Orion European Service Module is scheduled to be

delivered soon to the Operations and Checkout Building at KSC for integration with the Crew Module. NASA is accelerating the Ascent Abort-2 test (AA-2) into 2019, ahead of EM-1. Structural work is already underway on Orion EM-2 flight hardware production. Orion has continued qualification testing of systems for EM-2. This year, EGS will complete the system verification and validation phase and begin the operations and integration phase in preparation for multi-element verification and validation for the Mobile Launcher, Pad, and Vehicle Assembly Building.

NASA will also begin to build the in-space infrastructure for long-term exploration and development of the Moon by delivering to lunar orbit a power and propulsion element (PPE), planned to be launched in 2022 on a commercial rocket, as the foundation of the Gateway. NASA released the PPE final Broad Agency Announcement (BAA) in September and proposals are due in November. This BAA is designed to leverage the commercial communication industry's extensive experience in building and operating spacecraft. The Gateway is envisioned to be a spacecraft operating in the vicinity of the Moon that demonstrates crewed and uncrewed operations in deep space. It will be incrementally built in place using SLS, the Orion crew vehicle, and commercial launch vehicles. The Gateway will be assembled in lunar orbit where it can be used as a staging point for missions to the lunar surface and destinations in deep space, providing a flexible human exploration architecture depending on mission needs. Although there are various concepts for its configuration, current analysis suggests the initial functionality will include four main capabilities: PPE; habitation; airlock to enable science and EVA; and logistics for cargo delivery, science utilization, exploration technology demonstrations, and potential commercial utilization. With the initial habitation capabilities delivered to cislunar space, crews of four – launched on Orion – will visit the Gateway on missions initially lasting 30 days and up to 90 days as new modules are added to complete Gateway's full capabilities.

Gateway will enable system and operational demonstrations, scientific exploration, biological and biomedical science, and will serve as an eventual aggregation and departure point for crewed missions to the lunar surface and other deep space destinations. The Gateway will serve as a critical platform to conduct biological and biomedical studies that require a beyond-LEO space environment to study the response of biology (human and non-human organisms) to this new environment. A key science-enabling feature of this spacecraft is exposure of organisms to the deep space radiation environment for radiation and combined radiation/microgravity studies. The Gateway will also serve as a platform to mature necessary short- and long-duration deep space exploration capabilities in the 2020s, including highly reliable and dormancy-tolerant environmental control and life support systems; logistics reduction capabilities; advanced in-space propulsion; automated rendezvous and docking; radiation monitoring and mitigation capabilities; and integrated human-robotic mission operations, to name a few.

NASA has established the Lunar Discovery and Exploration Program (LDEP) in the Science Mission Directorate and is leveraging the Agency's extensive lunar science experience and data for lunar exploration. We are jump-starting commercial partnerships, innovative approaches for building and launching sophisticated next-generation science instruments, and the development of small rovers that will reach the Moon's surface via commercial landers. The Agency is integrating science and human exploration goals, including the eventual return of humans to the Moon. Just this past year, scientists used data from NASA's Lunar Reconnaissance Orbiter to identify areas in lunar craters that are cold enough to have frost present on the surface – ice that could provide crucial resources for exploration while also containing valuable information about the chemical makeup of the early solar system.

NASA is supporting the development of commercial lunar exploration capabilities leading to a human lunar landing. The Advanced Cislunar and Surface Capabilities (ACSC) program in the Human Exploration and Operations Mission Directorate will focus on engaging U.S. industry partners using innovative approaches to combine lunar robotics, a cislunar presence, and lunar landing capabilities

building up to a human-rated lander. In 2019, ACSC and LDEP will support initial risk reduction activities by incorporating results from the following.

- The Lunar Cargo Transportation and Landing by Soft Touchdown (CATALYST) initiative 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 request for proposals (RFP) for Commercial Lunar Payload Services (CLPS) on September 6, 2018, encouraging the U.S. commercial space industry to introduce new technologies to deliver payloads to the Moon. NASA intends to award multiple contracts for these services through the next decade, with contract missions to the lunar surface expected to begin as early as 2019, and with a company's first delivery no later than Dec. 31, 2021.

- NASA is also working on the second phase of the Next Space Technologies for Exploration Partnerships (NextSTEP), an effort to stimulate deep-space capability development across the aerospace industry. Through NextSTEP, the Agency intends to seek proposals from industry in support of design analysis, technology maturation, system development and integration, and spaceflight demonstrations for human-class lunar landers. This will address the development of medium- to large-scale lunar lander capabilities that have extensibility to reusable, human-class landers to a wide range of destinations on the lunar surface.

Ultimately, the Moon 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.

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;
- 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.

Exploration Technology

Critical to the Exploration Campaign, NASA will conduct research and promote technology development to address needs for human and robotic space exploration and to foster commercial expansion in LEO, cislunar space, and beyond. NASA's Technology research drives exploration by spanning the Technology Readiness Level spectrum, including investments in early-stage concepts and prototypes. Exploration Research and Technology key areas of focus will include:

- Advanced environmental control and life support systems;
- In-Situ Resource Utilization (ISRU);
- Nuclear and solar power and propulsion technologies for exploration;
- Advanced communications, navigation, and avionics;
- In-space manufacturing and on-orbit assembly;
- Advanced materials;
- Entry, Descent, and Landing;

- Autonomous operations; and
- Research to enable humans to safely and effectively operate in various space environments.

NASA continues to partner with researchers across academia, industry, and within the Agency to explore transformative technologies and approaches. Upcoming early-stage innovation activities will investigate areas such as breakthrough propulsion, challenges in deep space human habitation, space-optimized energy systems, radiation protection, and materials. These areas are part of a comprehensive approach to efficiently support innovative discovery, progress toward important goals, and development of exciting new capabilities.

In August, NASA selected 10 proposals from six U.S. companies, with a combined award value of approximately $44 million, to develop commercial space capabilities that benefit future NASA exploration missions in new public-private partnerships, including lunar lander and deep space rocket engine technologies. While these "Tipping Point' partnership selections will enable NASA's future science and human exploration missions, these awards will also grow the economy and strengthen the Nation's economic competitiveness.

This past spring, NASA also selected 10 companies to conduct studies and advance ISRU technologies to collect, process, and use space-based resources for missions to the Moon and Mars. ISRU could increase safety and affordability of future human spaceflight missions by limiting the need to launch supplies such as oxygen and water from Earth. In the area of Flight Opportunities, suborbital flight providers are now on the verge of a significant leap forward, and payloads are beginning to fly from multiple providers. Given this success, NASA will shift our focus to funding more payload flights. To date, Flight Opportunities has enabled 122 flights of 93 payloads. There are an additional 62 payloads awaiting flight. Later this year, we look forward to the launch of the Green Propellant Infusion Mission and the Deep Space Atomic Clock on the U.S. Air Force's Space Technology Mission-2 on a SpaceX Falcon Heavy booster.

Planetary Science

NASA's Planetary Science program develops and operates missions that explore our solar system and search for life elsewhere, helping to answer fundamental questions about our place in the universe. NASA's Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) lander launched on May 5 of this year, and will land on Mars on November 26, joining a series of NASA rovers, landers, and orbiters already at the Red Planet. InSight's advanced payload will provide unique information on the interior structure of Mars, providing glimpses into the processes that shaped the rocky planets of the inner solar system. The Agency is also working on the Mars 2020 rover and planning for a potential Mars Sample Return mission incorporating commercial and international partnerships – a top priority identified by the scientific community in the most recent National Academy of Sciences (NAS) planetary decadal survey. In addition, we received radio signals indicating that the first-ever CubeSats headed to deep space are alive and well. Launched along with InSight, Mars Cube One, or MarCO, is a pair of briefcase-sized spacecraft that will test out miniature spacecraft technology along the way to Mars.

On December 3, 2018, NASA's Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx) mission will arrive at the asteroid Bennu, providing unique data that will shed light on the early history of the solar system. OSIRIS-REx measurements of the composition of the potentially hazardous Bennu will also inform the design of future missions to mitigate asteroid impacts on Earth, an effort aligned with and supporting NASA's new Planetary Defense program. On January 1, 2019, the New Horizons spacecraft will fly by a Kuiper Belt Object, returning new information about the unusual bodies that occupy this distant part of our solar system. During 2018, NASA has continued development of the cutting-edge Europa Clipper mission to fly by Jupiter's ocean moon, and

will announce the next scientifically and technologically innovative New Frontiers mission: either a comet sample return or a drone to explore Saturn's largest moon, Titan.

Astrophysics

NASA's Astrophysics program investigates the origin and evolution of the universe and the formation of planetary systems. It examines how environments hospitable for life develop, and contributes to the search for the signature of life on other worlds. The program operates the Hubble, Chandra, Spitzer, Fermi, Kepler, Swift, Nuclear Spectroscopic Telescope Array (NuSTAR), and the Transiting Exoplanet Survey Satellite space telescopes, flies the airborne Stratospheric Observatory for Infrared Astronomy (SOFIA), and conducts balloon and suborbital rocket campaigns.

NASA's impressive observatories will be joined by the James Webb Space Telescope, which will detect the first stars and galaxies that formed after the big bang, and will take the next giant leap in characterizing planets orbiting other stars and searching for Earth-like planets. Successfully implementing the Webb mission is a high priority and critical to maintaining national leadership in the space sciences.

Webb is in the final stages of its development. All of its hardware has been fabricated, and the flight hardware and software are undergoing the last major steps of its integration and testing (I&T) phase. However, early this year, NASA recognized that it would take longer to complete the Spacecraft element I&T than previously estimated. NASA formed an Independent Review Board (IRB) chaired by A. Thomas Young, a distinguished leader of the aerospace community. After considering the IRB's recommendations, NASA has established March 30, 2021, as Webb's new launch date, and the estimated development cost, including launch and commissioning, has risen to slightly over $8.8 billion, up from the nearly $8 billion development-cost estimate established in 2011. We have not yet determined what impacts this cost overrun will have on other NASA programs and projects, but our plan will be informed by the priorities established through the National Academy's decadal surveys. We look forward to providing our funding plan for successful completion of Webb to this Committee as part of the FY 2020 budget request.

Two new astrophysics missions were launched to the ISS in 2017 – the Neutron Star Interior Composition Explorer (NICER) in June and the Cosmic Ray Energetics and Mass (CREAM) experiment in August of that year. NICER is the first NASA mission dedicated to studying pulsars – the densest observable objects in the universe, and CREAM monitors the cosmic rays that constantly shower the Earth. The Transiting Exoplanet Survey Satellite (TESS), launched on April 18, 2018, is NASA's next planet-hunting mission, searching for planets orbiting nearby stars. In August 2017, NASA selected six astrophysics Explorer Program proposals for concept studies. The proposed missions will collect unprecedented measurements of gamma-ray and X-ray emissions from galaxy clusters and neutron star systems, infrared emissions from galaxies in the early universe, and atmospheres of exoplanets. In January 2019, NASA will select at least two of these proposals for flight.

Heliophysics

NASA's Heliophysics program studies how the Sun affects the Earth and objects around it, how it influences other planets in the solar system, and how our star affects the very nature of space itself. Improved understanding of the Sun and information about the space weather phenomena it produces is used to provide warnings and better protect lives and essential – but vulnerable – systems on Earth, as well as to safeguard astronauts, satellites, and robotic missions traveling through the solar system. The program includes operation of, and analysis of data from, the Solar Dynamics Observatory (SDO), the joint European Space Agency (ESA)-NASA Solar and Heliospheric Observatory (SOHO), and the Solar

Terrestrial Relations Observatory (STEREO). These assets will be joined by future assets such as the ESA-NASA Solar Orbiter Collaboration (SOC), currently in development. Together, they constantly monitor the Sun, revealing coronal mass ejections and releases of solar energetic particles, while also advancing scientific understanding of our star's fundamental dynamics. Closer to Earth, the Magnetospheric Multiscale (MMS) mission uses four small spacecraft flying in formation to gather information on Earth's magnetic environment, changing our understanding of how that environment protects our planet.

The Global-scale Observations of the Limb and Disk (GOLD) instrument was launched aboard a commercial communications satellite in January 2018, and the Ionospheric Connection Explorer (ICON) spacecraft is slated for launch later this year. Together, they will provide the most comprehensive observations of the ionosphere – a region of charged particles in Earth's upper atmosphere – ever achieved. The Geospace Dynamics Constellation (GDC) mission, which is currently nearing the end of its definition phase, will provide key understanding of the interaction of various regions in geospace where space weather has its greatest impact on space assets. The Space Environment Testbed 1 mission, a technology demonstration mission developed in partnership with the United States Air Force, is scheduled for launch in 2018, and three heliophysics CubeSats are being prepared for launch as part of NASA's CubeSat Launch Initiative. Perhaps most exciting is the recent launch of the Parker Solar Probe, which began its journey last month, and will make its first close fly-by of the Sun in November. This historic mission will be the first to travel through the Sun's atmosphere, providing humanity with the closest-ever observations of a star.

In July 2017, NASA selected five heliophysics Explorer Program proposals and three missions of opportunity for concept studies. The proposed missions will investigate fundamental space physics energization and coupling phenomena in the Sun's extended atmosphere and in Earth's magnetosphere, and develop observation techniques directly applicable to space weather capabilities. In December, NASA will select at least one mission of opportunity and in March 2019, will select at least two explorer proposals for flight.

These assets join other missions in the Heliophysics Great Observatory, working in concert to provide the nation with critical data to protect and improve life on Earth.

Earth Science

NASA's Earth Science program makes revolutionary observations of our planet's land, oceans, and atmosphere from the vantage point of space; combines measurements of many different quantities to understand and accurately model the Earth's complex system of interacting processes; and provides practical benefits by transforming the measurements and understanding into focused information products that are used broadly to improve the quality of life for all humans.

In August and September 2017, data products from NASA Earth-observing research satellites were used to support real-time decision making, response, and recovery planning efforts by the Federal Emergency Management Agency, other operational agencies, and first responders on the ground in the affected areas during the catastrophic landfalls of hurricanes Harvey, Irma, and Maria.

NASA's Earth Science program is also pioneering innovative partnerships and mission strategies to achieve science goals rapidly and cost-effectively, including pilot data buys and evaluations of data products from commercial, on-orbit small-satellite constellations. The low-cost, competitively-selected ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) instrument to measure agricultural water use in the United States and vegetation stress around the globe, and to identify drought warning conditions, was launched to the ISS on June 29, 2018. Two major competitively

selected payloads – Tropospheric Emissions: Monitoring of Pollution (TEMPO) to measure North American air quality, and Geostationary Carbon Cycle Observatory (GeoCarb) to measure natural carbon flux processes in the western hemisphere – are being developed for flight as hosted payloads on commercial communications satellites.

Launching in 2018, two important NAS-decadal-survey-recommended missions will expand the long-term collection of key Earth observations. Making precise measurements of gravity from two spacecraft, the GRACE Follow-On mission (a partnership with German research and space agencies, which launched on May 22, 2018), will provide global information on ice sheet and oceanic mass balances, underground water storage changes in aquifers, and regional drought conditions. The Ice, Cloud and land Elevation Satellite-2 (ICESat-2) was launched on Sept. 15 to map and monitor land ice topography and glacier flow, sea ice thickness, and the heights of the vegetation canopy at low- and mid-latitudes across the globe. NASA remains on track to launch Landsat-9 in December 2020.

NASA's Joint Agency Satellite Program brings NASA's best practices to bear to support our interagency customer NOAA in the development of critical weather satellites for the Nation. The Joint Polar Satellite System-1 (JPSS-1, now NOAA-20) successfully launched in November 2017, and Geostationary Operational Environmental Satellite-S (GOES-S, now GOES-17) successfully launched in March 2018.

Aeronautics Research

NASA's work has always strengthened our security and the economy, and our ongoing research and testing of new aeronautics technologies is critical in these areas. This work will help us lead the world in a global aviation economy with increasing benefits worldwide. X-planes, Urban Air Mobility, commercial supersonic flight, unmanned aviation systems, advanced hypersonics technologies, and the next generation of aircraft are critical focuses of NASA's research. NASA's Aeronautics Research program advances U.S. global leadership by developing and transferring key enabling technologies to make aviation safer, more efficient, and more environmentally friendly. The Agency is working on critical concepts and technologies required to support continued global leadership in civil aviation.

NASA recently awarded a competitive contract for detailed aircraft design, build, and validation of the Low-Boom Flight Demonstrator (LBFD) X-plane, now designated the X-59 QueSST. The X-59 will demonstrate quiet overland supersonic flight and enable U.S. industry to open a new market and is on track for first flight by FY 2021. Data generated from flights of this demonstrator will feed directly into national and international regulatory decision-making processes and timelines, enabling a rule change to allow civil supersonic flight over land. NASA will also continue to advance new subsonic aircraft technologies that will dramatically reduce fuel consumption, noise, and emissions through a combination of numerical analyses, ground tests, and flight experiments.

NASA's Aeronautics work includes developing revolutionary tools and technologies such as hybrid and all-electric aircraft, autonomy, advanced composite materials and structures, data mining, verification and validation of complex systems, and revolutionary vertical-lift vehicles. This work enables further advances for transformative vehicle and propulsion concepts that will address a broad array of our aviation industry's needs. For example, in partnership with industry, NASA is delivering a variety of computational tools and guidance that will significantly reduce the time needed to develop and certify new composite structures for aerospace applications.

NASA is advancing the state of the art in key technologies needed to realize practical larger-scale hybrid electric propulsion systems for the future. We will be flight-testing an advanced configuration of the X-57 Maxwell aircraft, a general-aviation-scale aircraft to test highly integrated distributed electric propulsion technology. This demonstration will address the integration of electrical and power

distribution components critical to development of standards and certification methodologies required to enable widespread use of electric and hybrid electric propulsion in civil aviation, and eventually in commercial airline fleets.

NASA is demonstrating new air traffic management (ATM) tools that integrate aircraft arrival, departure, and airport surface operations to reduce flight delays and increase air traffic capacity and safety, supporting realization of the Federal Aviation Administration's (FAA's) full vision for the Next Generation Air Transportation System (NextGen). Even with limited operational trials at the Charlotte Douglas International Airport, technologies being developed by the ATM Technology Demonstration-2 Project are already showing significant savings in fuel burns and delays during taxi operations.

NASA is advancing the realization of routine access of Unmanned Aircraft Systems (UAS) into the National Airspace System for civil use by completing flight testing of detect and avoid (DAA) and communications technologies, and providing the data to standards development committees and the FAA to support UAS rule making. Additionally, NASA will help support safe, low-altitude operations of small UAS through development and demonstration of the UAS Traffic Management concept (UTM) in high-density urban areas. This comprehensive demonstration of the UTM concept in the most challenging operational environment will set the stage for transition to and implementation by the FAA and industry.

NASA's hypersonic fundamental research will enable development of tools and methods to more efficiently design future hypersonic vehicles.

Today, we stand on the cusp of the next era in aviation. Recent technology advances are coming together to enable breakthroughs in the speed and efficiency of the transport aircraft that are the backbone of the aviation system. Other breakthroughs will enable new markets for smaller aircraft, from UAS that serve search and rescue, agricultural, and commercial applications to the potential for new modes of personal transport. Global competition is fierce in all of these markets. NASA's development of aircraft, UTM and Urban Air Mobility technologies will accelerate the U.S. competitive posture in the global race to achieve leadership in emerging air mobility markets. U.S. companies will build on these advances and introduce new commercial products ranging from small UAVs to air taxis to large commercial aircraft. These innovations will support new jobs, new opportunities, and new ways for the U.S. to lead the world in technology and innovation.

Conclusion

NASA will 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. The Agency will return astronauts to the Moon and encourage the creation of a thriving commercial space economy in LEO and beyond; monitor the Sun and Earth, explore the planets of our solar system, and observe the universe beyond; and make aviation safer, more efficient, and more environmentally friendly. We appreciate the Subcommittee's continued support, and I would be pleased to respond to your questions.