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Statement of

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before the

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Committee on Science, Space and Technology
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Overview

Mr. Chairman and Members of the Committee, I am pleased to have this opportunity to discuss NASA's FY 2019 budget request of $19.9 billion. This budget places NASA at the forefront of a global effort to advance humanity's future in space, and expands on our Nation's great capacity for exploration and innovation and exploration.

Pursuant to National Space Policy Directive-1, the request provides the FY 2019 resources NASA requires for its role in "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 request provides the resources NASA needs to lead a sustainable campaign of exploration, returning humans to the Moon for long-term exploration and utilization followed by human missions to Mars and other destinations.

With the FY 2019 request, NASA is proposing an Exploration Campaign funded at $10.5 billion in FY 2019 and $52 billion over five years. The Campaign is an an Agency-wide integrated research and development program that focuses interconnected exploration objectives. Within the Exploration Campaign, NASA will pursue a bold new lunar exploration program by employing expertise and resources across the Agency in support of: a science and technology initiative; a small commercial lander initiative; a development activity for commercial mid-to-large landers to address both science and human exploration objectives, and a Lunar Orbiting Platform-Gateway. The effort is built to enable early successes with seamless collaboration across the Agency, and foster both commercial and international partnerships towards progressive capability development and leadership.

The International Space Station (ISS) is a cornerstone of our integrated approach to exploration. NASA will use the full potential of the Station to demonstrate critical technologies, learn about human health in space, and focus commercial energies on the growing low Earth orbit (LEO) economy. Starting this year, we will accelerate the process of transitioning to commercial approaches to ensure a long-term human presence in LEO by the end of 2024 as NASA leads a coalition of international and commercial partners to the Moon and then Mars and beyond. We propose to end direct U.S. financial support for the ISS in 2025, after which NASA would rely on commercial partners for our LEO research and technology demonstration needs.

Deep space exploration will require a heavy-lift capability and a crew vehicle designed for the rigors of long-duration flights and high-speed reentry into the Earth's atmosphere. NASA will test these capabilities with the uncrewed launch of the new Space Launch System (SLS) and Orion crew vehicle on an initial mission around the Moon in FY 2020. In 2023, we will use these systems to launch humans into lunar orbit – the first human mission beyond LEO since 1972.

To establish a presence beyond LEO in the strategic region around the Moon, NASA will develop a Lunar Orbital Platform-Gateway. The Gateway will be a place to live, learn and work around the Moon and will provide opportunities to support missions to the surface. The FY 2019 request supports NASA's plan to launch the first element of the Gateway – its power and propulsion module – in 2022 and will do so by launching the element through competitive commercial launch contract in an effort to both accelerate the establishment of the Gateway and enable and further advance commercial partnerships in deep space.

NASA will draw on the interests and capabilities of our industry and international partners as we develop progressively complex robotic missions to the surface of the Moon with scientific and exploration objectives in advance of human return. In collaboration with our robust scientific activity across the NASA portfolio, these new lunar robotic missions will stretch the capabilities of industry and international partners, while returning science and knowledge we can use for human missions.

The FY 2019 request proposes a new Exploration Research and Technology budget line incorporating current Space Technology Mission Directorate (STMD) and some Human Exploration and Operation Mission Directorate (HEOMD) programs into an integrated technology investment line focused on exploration. These technology investments will enable new robotic and human exploration capabilities and missions, and they will contribute to economic development and growth by enabling innovative systems and services supporting the emerging space economy.

At the end of the five years proposed in the budget request for this Exploration Campaign, NASA plans to achieve uncrewed and crewed test launches of the SLS and Orion system; launched two of the initial elements of the Lunar Orbital Platform – Gateway (to be complete with two additional launches by 2025); supported numerous commercial lunar robotic landings and developed lunar landing capabilities to support future NASA mission needs; developed key technologies needed to make exploration more capable and cost-effective; and established a pathway to enable a seamless transition from direct NASA financial support of the ISS in 2025.

The FY 2019 request supports and expands science missions across the solar system while integrating science into the exploration campaign and leveraging NASA's extensive lunar science experience and data. As the Mars Curiosity rover continues to make dazzling discoveries, work continues on a sister Mars lander for launch in 2020. The budget provides for continued work on a potential Mars sample return mission, a Europa Clipper mission, and a constellation of operating planetary science missions. The request effectively triples funding for detecting and learning to respond to hazardous near-Earth objects (NEOs), funding a first-of-kind mission to deliberately alter the orbit of a near-Earth object. In Earth Science, the budget supports the priorities of the science and applications communities with a focused, balanced program including funding for Landsat-9 and a Sustainable Land Imaging program. The request supports the study of our nearest star with the launch later this year of the Parker Solar Probe, a mission that will endure high temperatures while travelling through the Sun's atmosphere to make the closest-ever observations of the Sun and, indeed, of any star. In Astrophysics, the James Webb Space Telescope, which is planned to launch in 2019, will go to the opposite extremes. With detectors operating just a few tens of degrees above absolute zero, the telescope will look out over vast distances and back into the early universe.

The FY 2019 request supports NASA's continuing research on new aeronautics technologies, including commercial supersonic flight, unmanned aviation systems, and the next generation of aircraft. NASA's Low-Boom Flight Demonstrator, an experimental supersonic airplane will make its first flight in 2021. This "X-plane" could open a new market for U.S. companies to build faster commercial airliners, creating jobs and cutting cross-country flight times in half.

The request proposes to terminate the Office of Education and its portfolio of domestic assistance awards (principally grants and cooperative agreements), redirecting those funds to NASA's core mission of exploration. NASA will continue to support other education activities, such as internships and fellowships funded by the mission directorates.

NASA's FY 2019 request supports the Agency's efforts to renew and sustain factilities crucial to mission success while divesting of unneeded infrastructure. The request maintains vital support for independent technical and safety oversight of NASA missions and operations.

Human Exploration and Operations

The FY 2019 request proposes an integrated, Agency-wide Exploration Campaign. The Campaign will be executed with the goals of establishing an innovative and sustainable program of exploration in concert with our commercial and international partners, to spur a vibrant commercial activity in low-earth orbit, and to enable human expansion across the solar system, bringing new knowledge and opportunities back to Earth. The United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations. The request provides the necessary resources in FY 2019 to support development as planned of the SLS rocket and Orion crew vehicle, as well as the other critical technologies and research needed to support a robust exploration program. The budget creates new opportunities for collaboration with industry on ISS and supports public-private partnerships for exploration systems that will extend human presence into the solar system. The budget supports our plan to deliver to lunar orbit in 2022 a power and propulsion element as the foundation of a Lunar Orbital Platform-Gateway.

The FY 2019 request includes a new account structure for human exploration and operations and space technology programs to improve alignment of programs and funding with NASA's new strategic space exploration objectives. This new structure includes LEO and Spaceflight Operations; Deep Space Exploration Systems; and Exploration Research and Technology accounts, and realigns some program content.

Consistent with the new budget structure and in order to focus Agency activity on exploration, NASA also plans to reorganize the Human Exploration and Operations Mission Directorate (HEOMD) and Space Technology Mission Directorate (STMD). NASA will assess restructuring options (and hybrid options that may be developed), and prepare for implementation at the start of the FY 2019 budget year.

The FY 2019 request includes $10.5 billion for the Exploration Campaign, with $4.6 billion for Deep Space Exploration Systems, and $1.0 billion for Exploration Research and Technology. The FY 2019 request also includes $4.5 billion for Low-Earth Orbit and Spaceflight Operations, including the International Space Station (ISS) and Space Transportation – both commercial crew system development and ongoing crew and cargo transportation services that resupply the ISS, as well as $44.8 million for the Exploration Campaign Construction of Facilities and $268 million for Moon and Mars exploration activities funded in the Science Mission Directorate.

The ISS will continue to serve as the Nation's core long-duration human spaceflight asset through 2024 – which will mark nearly 25 years of continuous human occupancy. However, NASA must also look

beyond its current programs in order to secure the nation's future in LEO. Starting in FY 2019, NASA proposes a new program designed to foster the emerging commercial LEO space industry. This program, starting with a $150 million investment in FY 2019, will support commercial partners to encourage development of capabilities that the private sector and NASA can utilize in LEO. The budget proposes to end direct U.S. financial support for the ISS in 2025, after which NASA would rely on these commercial partners for our LEO research and technology demonstration requirements. The decision to end direct Federal support for the ISS in 2025 does not necessarily imply that the platform itself will be deorbited at that time – it is possible that industry could continue to operate certain elements or capabilities of the ISS as part of a future commercial platform. NASA will encourage the emergence of an environment in LEO where NASA is one of many customers of a non-Governmental human spaceflight enterprise.

Maintaining the ISS requires a fleet of launch 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, are providing cargo deliveries to the ISS. Using the space launch vehicles developed in partnership with NASA, SpaceX and Orbital ATK have also helped to bring some of the commercial satellite launch market back to the United States and have reduced commercial launch costs. Under new CRS-2 contracts, SpaceX, Orbital ATK, 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 2018. The FY 2019 request provides critical resources in this exciting and challenging period as we work with our partners to launch the first new U.S. human spaceflight capability in a generation.

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.

As we move out beyond LEO, we will employ new deep space systems, including the heavy-lift SLS, Orion crew vehicle, the Exploration Ground Systems (EGS) that support them, commercial launch vehicles, lunar landers, and new deep space habitation capabilities to be developed through public-private partnerships and international partnerships.

NASA plans to launch an initial, uncrewed deep space mission, Exploration Mission-1 (EM-1), in FY 2019. The mission will combine the new heavy-lift SLS with an uncrewed version of the Orion spacecraft on a mission to lunar orbit. A crewed mission, EM-2, will follow in 2023. The FY 2019 budget fully funds the Agency baseline commitment schedule for EM-2 and the Orion spacecraft and enables NASA to begin work on post EM-2 missions. Missions launched on the SLS in the 2020s will establish the capability to operate safely and productively in deep space.

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. In FY 2018, SLS Core Stage integration and outfitting (including installation of the four RS-25 engines) will continue at Michoud Assembly Facility. There will be a series of EM-1 flight hardware deliveries to EGS at Kennedy Space Center (KSC). SLS will prepare for the EM-1 Design Certification Review planned for early 2019, conduct the Critical Design Review (CDR) for the next mission, EM-2, and begin fabrication of components for EM-3 and beyond. In FY 2018, Orion will continue qualification testing of systems for EM-2. 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. For EM-1, the European Service Module is

scheduled to be delivered to the Operations and Checkout Building at KSC for integration with the Crew Module. Later 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. These are the early steps on a journey that leads American astronauts into deep space, permanently.

We also will 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 as the foundation of a Lunar Orbital Platform-Gateway. The Gateway to the Moon and beyond will give us a strategic presence in cislunar space that will drive our activity with commercial and international partners and help us further explore the Moon and its resources and leverage that experience toward human missions to Mars. In-space power and propulsion and deep space habitation are central to future human exploration. Development and deployment of these capabilities will be a focus of the early-to-mid 2020s, leading to crewed missions beyond the Earth-Moon system, including to the Mars system.

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 these initial public-private partnerships, NextSTEP partners will provide advanced concept studies, technology development projects, and significant measurements in key areas, including habitat concepts, environmental control and life support systems, advanced in-space propulsion, and small spacecraft to conduct missions related to strategic knowledge gaps. NASA intends to perform integrated ground testing using habitation capabilities developed by the NextSTEP partners in 2018.

As part of the Agency's overall strategy to conduct deep space exploration, NASA is supporting the development of commercial lunar exploration. A new cross-Agency campaign will combine science and exploration objectives in Advanced Cislunar and Surface Capabilities . The campaign will focus on engaging non-traditional U.S. industry partners and sectors in the space program and using innovative approaches to combine lunar robotics, a cislunar presence, and lunar landing capabilities, involving commercial and international participation. For example, the purpose of the Lunar Cargo Transportation and Landing by Soft Touchdown (CATALYST) initiative is to encourage 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. Commercial robotic lunar lander capabilities could address emerging demand by private customers who wish to conduct activities on the Moon, even while providing cost-effective transportation services for NASA's science and exploration missions, thereby benefitting the larger scientific and academic communities. As part of the Exploration Campaign, we will initiate a series of robotic lunar missions in partnership with industry as early as 2019, eventually leading to a continual human presence on and around the Moon.

The budget request provides for critical infrastructure indispensable to the Nation's access and use of space, including those provided under Space Communications and Navigation, the Launch Services Program, Rocket Propulsion Testing, and Human Space Flight Operations.

New research, technologies, and capabilities lay the groundwork that enhances and enables deep space exploration. Exploration Research and Technology will consolidate the technology development program content previously funded by Space Technology and Advanced Exploration Systems, integrating and refocusing these activities toward Deep Space Exploration. This will enable NASA's outstanding workforce to focus on innovative ways to further humankind's exploration from conception to testing to spaceflight. The Human Research Program (HRP) will continue to conduct cutting-edge research on the effects of spaceflight on the human body, including experiments on the ISS in microgravity. HRP will support the development of Deep Space Exploration habitat concepts to ensure crew health and performance risks are adequately addressed.

NASA's FY 2019 request includes $1.0 billion for Exploration Research and Technology to conduct research to address needs for human and robotic space exploration and to foster commercial expansion in LEO, cislunar space, and beyond. Technology 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);
- 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.

Exploration Research and Technology will work with the Science Mission Directorate where appropriate on exploration-related technology and research that also has relevance to achieving science goals. In FY 2019 NASA will build on its initial investment in In-Space Robotic Manufacturing and Assembly, continuing a public-private partnership approach to flight-demonstrate new technologies used to build large structures in a space environment. In addition, technology development in satellite servicing will be aligned to support on-orbit assembly and manufacturing capabilities in collaboration with industry.

In FY 2019, the HRP will continue to implement the ISS flight research plan crucial to mitigating crew health and performance risk for exploration. HRP will complete ground testing of an advanced exploration exercise system in preparation for ISS deployment as part of exploration system maturation plans. HRP will also continue to work with Deep Space Exploration's Habitation development to define and evaluate deep space exploration system habitats.

Upon completion of hardware building, system integration, and test in FY 2018, the Laser Communications Relay Demonstration project will deliver the completed mission payload to support a FY 2019 launch. The outcome of this effort will prove optical communications technology in an operational setting, providing data rates up to 100 times faster than today's radio-frequency-based communication systems.

In mid-2018, the Green Propellant Infusion Mission spacecraft and the Deep Space Atomic Clock instrument will both be delivered to orbit as part of the U.S. Air Force Space Test Program-2 mission aboard a SpaceX Falcon Heavy booster. In FY 2019, both missions will complete their technology demonstrations. The Green Propellant Infusion Mission demonstrates a propulsion system using a propellant that is less toxic and has approximately 40 percent higher performance by volume than hydrazine, and which will reduce spacecraft processing costs. The Deep Space Atomic Clock demonstrates navigational accuracy improvements (with 50 times more accuracy than today's best navigation clocks) for deep space and improved gravity science measurements.

In late 2018, the Solar Electric Propulsion project will complete ground testing of the engineering development units for the magnetically-shielded Hall effect thrusters and begin fabrication of the flight units for demonstration. As part of ongoing work under the NextSTEP-1 awards, NASA plans to conduct vacuum chamber tests of high-power electric propulsion systems operating for 100 continuous hours.

NASAwill provide a number of technologies for the Mars 2020 mission including: Terrain Relative Navigation; Mars Oxygen ISRU Experiment; the Mars Environmental Dynamics Analyzer; and the Entry, Descent and Landing Instrumentation, with deliveries between Fall 2018 and Spring 2019 to support the mission need dates.

NASA continues to partner with researchers across academia, industry, and NASA 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 the development of exciting new capabilities.

NASA will continue to engage with the emerging small spacecraft industry, including through the CubeSat Launch Initiative. In 2019, Lockheed Martin will complete LunIR, which will test an infrared sensor through a Moon flyby, and Morehead State University will deliver Lunar IceCube to NASA to make infrared measurements of lunar volatiles. NASA will also launch its CubeSat Proximity Operations Demonstration, possibly as soon as April of this year. This mission will demonstrate rendezvous, proximity operations and docking using two 3-unit CubeSats.

Science

NASA uses the unique vantage points of space, airborne, and ground-based assets, as well as teams of scientists, engineers, and technologists to expand our knowledge of the Earth, our Sun and solar system, and the universe. NASA measurements and research advance critical understanding, inform decision-making, and improve the quality of life for citizens in the United States and humankind around the globe. NASA's FY 2019 budget requests $5.9 billion for NASA's Science program, including $2.2 billion for Planetary Science, $1.2 billion for Astrophysics, $691 million for Heliophysics, and $1.8 billion for Earth Science. The budget ensures that NASA continues to play an important role in safeguarding life on Earth: funding a robust Earth Science program, a dedicated Planetary Defense program for NEO detection and mitigation, and expanding research to improve predictions and forecasting of space weather. It enables NASA to develop and operate space missions that search for life and illuminate the secrets of the universe.

The budget integrates 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. Establishing a new Agency-wide Lunar Discovery and Exploration program and leveraging NASA's extensive lunar science experience and data, this budget jump-starts commercial partnerships, innovative approaches for building and launching next-generation precision science instruments, and the development of small rovers that will reach the Moon's surface via commercial landers.

The request supports a vigorous Planetary Defense Program. The Near-Earth Object Observations project will continue to fund ground-based NEO discovery, tracking, and characterization efforts, while laying the foundation for future space-based NEO detection missions. The Double Asteroid Redirection Test (DART) will demonstrate asteroid deflection technology. DART will use the kinetic impactor technique to change the orbit of a small moon circling the asteroid Didymos, which will be about seven million miles from Earth at its closest approach in 2022.

Maintaining a balanced science program and achieving high-priority science and applications objectives in a cost-effective manner requires that NASA be committed to – and execute – a full range of responsible and transparent program management practices, policies, and approaches. To this end, the Science Mission Directorate is engaging in innovative partnerships with commercial and international partners and promoting the use of small, less expensive satellites. Given its significant cost and competing priorities within NASA, the budget proposes termination of the Wide Field Infrared Survey Telescope (WFIRST). Remaining WFIRST funding is redirected towards other priorities of the astrophysics community, including competed astrophysics missions and research.

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 is being prepared for a May 2018 launch, and will land on Mars in November – 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 budget also enables essential progress to be made 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 planetary decadal survey.

In the coming year, NASA's Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx) mission will arrive at the asteroid Bennu later this year, 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. During 2018, NASA will continue 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.

NASA's Astrophysics program investigates the creation 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, and Swift space telescopes, flies the airborne Stratospheric Observatory for Infrared Astronomy (SOFIA), and conducts balloon and suborbital rocket campaigns. NASA's impressive observatories will soon be joined by the James Webb Space Telescope, which is progressing toward a 2019 launch. Webb will be larger and more powerful than any previous space telescope. It will be capable of examining the first stars and galaxies that formed, viewing the atmospheres of nearby planets outside our solar system, and informing our understanding of the evolution of our own solar system.

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. NICER is the first NASA mission dedicated to 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), scheduled for launch in March 2018, will be 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.

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 to safeguard astronauts, satellites, and robotic missions traveling through the solar system. The budget supports efficient, continued operation 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 and Terrestrial Relations Observatory (STEREO). 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. Focusing 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.

Heliophysics is preparing the launch of several innovative missions. 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 launches later in 2018. Together, they will provide the most comprehensive observations of the ionosphere – a region of charged particles in Earth's upper atmosphere – ever achieved. NASA and the National Oceanic and Atmospheric Administration (NOAA) are exploring a potential partnership to use a single launch vehicle for the Interstellar MApping Probe (IMAP) (the highest priority in the Heliophysics decadal survey) and a NOAA space weather monitoring payload. The partnership would provide NOAA access to the L1 Lagrange point for future space weather monitoring. 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 upcoming launch of the Parker Solar Probe, scheduled for August 2018. This historic mission will be the first to travel through the Sun's atmosphere, providing humanity with the closest-ever observations of a star.

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. Geostationary Operational Environment Satellite-R (GOES-R, now GOES-16) transitioned to NOAA operations in June 2017, and Joint Polar Satellite System-1 (JPSS-1, now NOAA-20) successfully launched in November 2017.

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.

From December 2016 through December 2017, NASA launched two Earth-observing technology demonstration CubeSats – ICECube and Microwave Radiometer Technology Acceleration (MiRaTa); the Cyclone Global Navigation Satellite System (CYGNSS) constellation of eight small satellites to measure rapidly evolving tropical storms and hurricanes using reflected Global Positioning System (GPS) signals from the ocean; and three key Earth observation instruments now mounted externally on the ISS (a Lightning Imaging Sensor (LIS); Stratospheric Aerosol and Gas Experiment-III (SAGE-III) to measure atmospheric ozone and aerosol profiles; and Total and Spectral Solar Irradiance Sensor-1 (TSIS-1) to precisely monitor solar radiation reaching the Earth).

In August and September 2017, data products from NASA Earth-observing research satellites were used to support real-time decision-making and response 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. Precise, broad-coverage observations from NASA's Global Precipitation Measurement (GPM) Core Observatory enabled forecasters to understand and track the storms, and to generate accurate flood predictions. A suite of NASA satellite missions, including the Soil Moisture Active Passive (SMAP) satellite, assisted with flood mapping and recovery planning.

NASA's Earth Science program is pioneering innovative partnerships and mission strategies to achieve science goals rapidly and cost-effectively. The budget accelerates NASA's pilot data buys and evaluations of data products from commercial, on-orbit small-satellite constellations; NASA will have Blanket Purchase Agreements with at least four private-sector small-satellite data providers in place by Spring 2018. 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, will launch to the ISS in mid-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 in this budget.

In January 2018, the National Academies released the 2017-2027 Earth Science Decadal Survey, "Thriving on Our Changing Planet." The decadal survey recognized the value of NASA's Earth Science Program and identified a suite of high-priority science and observation objectives for NASA's Earth Science Division.

Launching in 2018, two important 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, launching in Spring 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), the follow-on to NASA's ICESat and IceBridge missions, will launch in Fall 2018 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 to continue the critical land imaging series begun with our United States Geological Survey (USGS) partners in 1972. Consistent with the FY 2018 budget, the FY 2019 budget proposes to terminate OCO-3, DSCOVR Earth-viewing instruments, and CLARREO Pathfinder.

NASA's decadal-survey-endorsed Earth-observing satellite missions, along with the research, applications development, and Earth-focused technology maturation programs enabled by this budget, advance our understanding of the fundamental nature of our planet and improve everyday life on Earth for our fellow citizens.

Aeronautics

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. With a request of $634 million for Aeronautics, the FY 2019 budget invests in the most critical concepts and technologies required to support continued global leadership in civil aviation.

In in the coming weeks 2018, NASA will award a competitive contract for detailed aircraft design, build, and validation of the Low Boom Flight Demonstrator (LBFD) X-Plane that will demonstrate quiet overland supersonic flight and enable U.S. industry to open a new market to U.S. industry. In FY 2019, NASA will ensure the LBFD X-plane is on track for first flight by FY 2021. NASA also will continue to develop and validate community response test methodologies which will be employed during the subsequent LBFD flight campaign. Data generated from flights of this demonstrator will feed directly into national and international regulatory decision making processes and timelines, enabling a rule change that will 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 request for Aeronautics will invest in developing revolutionary tools and technologies ranging from hybrid and all-electric aircraft, autonomy, advanced composite materials and structures, data mining, verification and validation of complex systems, and revolutionary vertical lift vehicles, to enabling further advances for transformative vehicle and propulsion concepts that will address a broad array of our aviation industry's needs. In partnership with industry, NASA will complete the Advanced Composites project, 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 will advance electric propulsion systems by 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 this technology. NASA also will advance the state of the art of key technologies needed to realize practical larger-scale hybrid electric propulsion systems for the future.

NASA will demonstrate 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 is already showing significant savings in fuel burns and delays during taxi operations. NASA will accelerate development and complete the transfer to FAA of key weather-related technologies for efficient enroute operations. NASA will explore new, innovative solutions for proactively mitigating the risks of using new vehicle technologies, leveraging the recently published National Research Council study on In-Time Aviation Safety Management as well as partnerships with the FAA and aviation industry. In FY 2019, NASA will demonstrate and validate tools which can be used for safety assessment of ATM and avionics systems, and transfer them to the FAA and the avionics industry.

NASA will advance the realization of routine access of Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS) 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 FY 2019 request increases funding for hypersonic fundamental research which will enable development of tools and methods to more efficiently design future hypersonic vehicles.

Across all of these research areas, NASA investments will nurture U.S. university leadership in innovation that will foster and train the future workforce, and leverage non-aerospace technology advancements. Specifically, NASA will continue to see benefits from the University Leadership Initiative in which university-led research teams independently analyze the technical barriers inherent in achieving the Aeronautics Research Mission Directorate strategic outcomes, and who have proposed multi-disciplinary technical challenges, along with supporting activities to address those barriers.

Education

NASA's FY 2019 budget proposes the termination of NASA's Office of Education and its portfolio of domestic assistance awards (grants and cooperative agreements), and instead prioritizes funding toward supporting an innovative and inspirational program of exploration. While the FY 2019 budget no longer supports these programs, a common vision, mission, and focus areas will drive NASA's future endeavors in science, technology, engineering, and mathematics (STEM) and public engagement. Through its mission directorates, NASA will focus on: creating unique opportunities for students to contribute to NASA's work in exploration and discovery; building a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content, and facilities; and strengthening understanding by enabling powerful connections to NASA's mission and work. A small team at NASA headquarters will be accountable for the strategic direction and coordination of the Agency's STEM engagement efforts.

NASA's mission successes will continue to inspire the next generation to pursue science, technology, engineering, and mathematics studies, join us on our journey of discovery, and become the diverse workforce we'll need for tomorrow's critical aerospace careers. We will use every opportunity to engage learners in our work and to encourage educators, students, and the public to continue making their own discoveries.

Mission Support

NASA's mission support programs directly enable the Agency's portfolio of missions in aeronautics, technology development and space exploration. The FY 2019 request prioritizes the capabilities, operations and equipment to safely operate and maintain NASA Centers and facilities, along with the independent technical authority required to reduce risk to life and program objectives for all NASA missions. With installations in 14 states, NASA collectively manages $39 billion in assets with an inventory of over 5,000 buildings and structures. Our focus is on renewing and sustaining what is crucial to mission success and divesting of unneeded, costly infrastructure to lower the cost of operations. In the transformation of information technology (IT) services, we are enhancing agency IT portfolio management and strengthening NASA's cybersecurity capabilities to safeguard critical systems and data.

Over the last several years, NASA Office of the Chief Information Officer (OCIO) has made significant progress in updating IT security policies, processes, and procedures to support the ongoing enhancement and automation of information system monitoring and reporting.

In FY 2019, OCIO will continue working toward improving NASA's compliance with the Federal Information Technology Acquisition Reform Act (FITARA) and the Federal Information Security Modernization Act (FISMA). Additionally, NASA OCIO will continue to implement improved management practices and efficiencies recommended by an internal IT Business Services Assessment . For example, NASA is continuing to evolve from a from a highly decentralized IT environment controlled by the Centers and Agency programs and projects to an enterprise IT environment that is more centrally managed and overseen by the Agency Chief Information Officer. This important transition,

along with other internal governance and infrastructure changes, is contributing to a stronger cybersecurity posture at NASA. While there is no perfect, one-size-fits-all tool to predict, counter and mitigate the wide range of attacks experienced across the Federal Government, new cybersecurity management tools will continue to allow NASA and other Federal agencies to have better insight into their networks, providing improved pro-active monitoring and mitigation of threats before they cause significant harm.

Conclusion

The President's FY 2019 budget request enables NASA to develop and operate technologies and systems for the human exploration of deep space and encourages the creation of a thriving commercial space economy in LEO and beyond; ensures robust programs of robotic missions to monitor the Sun and Earth, explore the planets of our solar system, and observe the universe beyond; and supports continuing advances to make aviation safer, more efficient, and more environmentally friendly.

Mr. Chairman, I would be pleased to respond to your questions and those of other Members of the Committee.