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COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES APPROPRIATIONS FOR FISCAL YEAR 2019

WEDNESDAY, MAY 23, 2018

U.S. SENATE,
SUBCOMMITTEE OF THE COMMITTEE ON APPROPRIATIONS,
Washington, DC.

The subcommittee met at 2:28 p.m., in Room SD–192, Dirksen Senate Office Building, Hon. Jerry Moran (Chairman) presiding.

Present: Senators Moran, Murkowski, Capito, Schatz, and Van Hollen.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

STATEMENT OF HON. JAMES F. BRIDENSTINE, ADMINISTRATOR

OPENING STATEMENT OF SENATOR JERRY MORAN

Senator MORAN. My hand will work as the gavel this afternoon.

We are going to start just a couple minutes early. The vote is at 3:15, and so this will be similar to the hearing that we had last week when we were under similar circumstances with the FBI Director.

Good afternoon. I call this hearing to order.

I am pleased to be joined today by the Acting Ranking Member of this subcommittee, Senator Schatz. I chaired a subcommittee that he was the ranking member of before I came here, and he has followed me in this capacity. And I look forward to working with you and your colleagues on this particular issue of Commerce, Justice, Science, the National Aeronautics and Space Administration.

Administrator, we are delighted to have you join us. I look forward to the conversation.

In light of the time constraints, I am going to forego an opening statement, and I now turn to the Senator from Hawaii, Senator Schatz.

STATEMENT OF SENATOR BRIAN SCHATZ

Senator SCHATZ. Thank you, Mr. Chairman. It is good to be back with you, Chairman Moran.

Thank you, Administrator Bridenstine, for being here.

I would also ask to enter both my statement into the record and Ranking Member Shaheen's statement into the record.

Senator MORAN. Without objection.

[The statements follow:]

PREPARED STATEMENT OF SENATOR BRIAN SCHATZ

Thank you, Mr. Chairman, and welcome Administrator Bridenstine.

The President has requested $19.9 billion for NASA as a whole, which is 4 percent lower than what the Congress enacted in fiscal year 2018. This budget repeats requests we rejected last fiscal year:

—Zero-ing out education

—Cutting Earth Science and next generation transportation systems

It is useful to know that the administration's position on these programs, but make no mistake: the Committee believes they are priorities, and we will continue to enact funding for them. They are necessary for NASA to serve the American people through a balanced portfolio of space, aeronautics, and science.

I have no argument with the budget's attention to human space travel—except that it seems to come at the expense of important programs that drive innovation, enable stewardship of the planet, and ensure an American workforce ready for the STEM jobs of tomorrow.

To underscore my concerns, consider the Carbon Monitoring System, or CMS, which NASA just eliminated. Administrator Bridenstine, I appreciate our conversation and your assurances that funding will continue for grants that have already been made. I also think you made interesting points about NASA's other carbon observations, and I will use my time later to give you a chance to share those points here today.

But the CMS is still a $10 million/year grant program that supports academic science in atmospheric carbon. This is the heart of what I mentioned earlier:

—funding for innovation

—supporting universities that educate tomorrow's STEM workforce

—making factual observations of our environment.

I can accept that a specific program like the CMS may no longer fit into NASA's portfolio of observations and science—but I sharply question the systemic cuts proposed in the fiscal year 2019 budget to Earth Science. The stakes are too high. We need impartial data from trustworthy sources like NASA to make smart decisions about how we manage resources and set policy for the future.

We also need an educated workforce to innovate economic growth from NASA science, which makes the proposal to zero out education particularly disappointing. For the kids and teachers in States like mine where Space Grant inspires and educates, I have a message: don't worry. Last year, we rejected the proposal to terminate NASA education, and we will do it again this year.

As for the budget's focus on human space travel to the moon as a stepping stone to Mars, I withhold judgment. It's a logical step, but I worry that increasing costs and delay wind up with us stalled at the moon indefinitely. The Government Accountability Office's most recent assessment of major NASA projects illustrates my concerns. The GAO found an average schedule delay of 1 year, up from 7 months last year, and average costs growing at least 18.8 percent—up from 15.6 percent last year.

Administrator Bridenstine, you and I had a good conversation last week, and I hope it will be a strong foundation for working together. We will need to, if we want to deliver the NASA that America needs and deserves.

PREPARED STATEMENT OF SENATOR JEANNE SHAHEEN

Thank you Mr. Chairman and welcome Administrator Bridenstine.

Overall, the National Aeronautics and Space Administration (NASA) budget request is $19.9 billion, a cut of 4 percent below the fiscal year 2018 level. The request repeats cuts Congress rejected in fiscal year 2018, including eliminating education programs and cutting funding for next generation transportation systems and Earth Science—items that are priorities of this Committee because they help NASA achieve the agency's calling to explore, discover, teach and inspire.

Such cuts threaten to stymie NASA's progress in achieving its missions and goals. Just as the administration's ambitious plans to return to the Moon rely on the deep space exploration vehicles, Orion and the Space Launch System (SLS), so does it also rely on having a technically-literate science and engineering workforce.

That's why I'm so disappointed by the repeated request to eliminate NASA Education programs. The New Hampshire Space Grant is inspiring a love of science in K–12 students and helping support undergraduates and graduate students through scholarships, fellowships and internships. Through research grants and educations programs like Space Grant and EPSCOR, every State is a space State.

I was glad to see your recent comments regarding climate change, Mr. Administrator. The science on climate change is beyond rational dispute: It is a reality—

a clear and present threat to our planet—and it must be addressed robustly and urgently.

When it comes to climate change, NASA's job is to observe the Earth—to tell us factually what is happening to our planet. NASA does not say why Earth's climate is changing or what policies we need to design in response. Yet NASA's fiscal year 2019 budget request cuts its core Earth observation by more than 7 percent, ending 4 missions. If this Nation is to make any progress in mitigating the harmful effects of climate change, we need science agencies, such as NASA, to provide factual and reliable information on how our world is changing.

Finally, I'd like to note that the Government Accountability Office (GAO) in its assessment of NASA large projects reports that the cost and schedule performance has deteriorated over the last year. Exploration Mission-1 has slipped in to 2020 and the James Webb Space Telescope is facing 18 months of delay due to issues like using the wrong cleaner, the wrong voltage or the wrong torque. NASA can't afford its vast ambitions if NASA and its contractors cannot even tighten screws correctly.

You may not think of New Hampshire as a space State, but indeed we are. We are the home State of Alan Shepard, the first American in space, and Christa McAuliffe, our teacher in space who died in the Challenger accident. Today, New Hampshire companies and universities supply NASA with technology to improve both low-orbit and deep space exploration and design, build and operate major instruments on NASA satellites to study solar physics.

I look forward to working with you and the Chairman to ensure NASA can help inspire and train the next generation of technical workers, whether they are building rockets or building American industry and products in the private sector.

Again, thank you for testifying today.

Senator SCHATZ. Thank you, Chairman.

Senator MORAN. Administrator Bridenstine, we welcome your testimony. While you may have been instructed to make it abbreviated, I think we are going to have time to hear from you, and I would encourage you to tell us what you would like for us to know. And if we run into trouble, we will try to work on cutting our questions short, which suggests you may want to go long.

Mr. BRIDENSTINE. Okay.

SUMMARY STATEMENT OF HON. JAMES F. BRIDENSTINE

Well, Mr. Chairman and Mr. Ranking Member, it is an honor to be here. I have, of course, submitted my written statement for the record. I know, because of the time constraints, that we are short on time, and I would be happy to forego an opening statement and just say this, that I have been charged with leading one of the most storied agencies in the United States Government. It is the honor of a lifetime. We have people doing very dangerous things even right now on the International Space Station and flying missions all over the world to deliver science and discovery not only on behalf of this Nation but on behalf of the entire world. So it is an honor. I am thrilled to be here, and I look forward to answering your questions.

[The statement follows:]

PREPARED STATEMENT OF HON. JAMES F. BRIDENSTINE

OVERVIEW

Mr. Chairman and Members of the subcommittee, I am very pleased to appear before you today, in my first opportunity to testify before Congress as NASA Administrator, to discuss NASA's fiscal year 2019 budget request of $19.9 billion. This budget, along with the fiscal year 2018 NASA appropriation included in the recently enacted fiscal year 2018 Consolidated Appropriations Act, 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.

Pursuant to National Space Policy Directive-1, the request provides the fiscal year 2019 resources NASA requires for its role in "an innovative and sustainable pro-

gram 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 fiscal year 2019 request, NASA is proposing an Exploration Campaign funded at $10.5 billion in fiscal year 2019 and $52 billion over 5 years. The Campaign is 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 Orbital Platform-Gateway (or "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 fiscal year 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 the 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 fiscal year 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 a 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 fiscal year 2019 request proposes a new Exploration Research and Technology budget line incorporating current Space Technology Mission Directorate (STMD) and some Human Exploration and Operations 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 5 years proposed in the budget request for this Exploration Campaign, NASA plans to have achieved uncrewed and crewed test launches of the SLS and Orion system; launched two of the initial elements of the 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 fiscal year 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 traveling 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 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 fiscal year 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 fiscal year 2019 request supports the Agency's efforts to renew and sustain facilities 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 fiscal year 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 LEO, 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 fiscal year 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 the Gateway.

The fiscal year 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 fiscal year 2019 budget year.

The fiscal year 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 fiscal year 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 fiscal year 2019, NASA proposes a new program designed to foster the emerging commercial LEO space industry. This program, starting with a $150 million investment in fiscal year 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. Government funding for the ISS in 2025, after which NASA would rely on these commercial partners for our LEO research and technology demonstration requirements. This decision 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. On May 17, NASA issued a NASA Research Announcement (NRA) for LEO Commercialization to inform NASA's strategy for enabling the commercialization of human spaceflight in LEO and meeting NASA's long-term LEO needs. The NRA solicits industry concepts, business plans and viability for habitable platforms, whether using the ISS or free-flying, that would enable a commercial marketplace in LEO where NASA is one of many customers. The NRA also seeks industry input on the role of government and evolution of ISS in the roadmap to commercialization of LEO. NASA anticipates awarding multiple four-month, fixed price contracts, up to $1 million per award.

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 5 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 fiscal year 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 fiscal year 2020. 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 fiscal year 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 fiscal year 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 continue a series of EM–1 Design Certification Reviews, conduct the Critical Design Review (CDR) for the next mission, EM–2, and begin fabrication of components for EM–3 and beyond. In fiscal year 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 the 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. On April 27, the NASA Science Mission Directorate issued a draft Request for Proposals for Commercial Lunar Payload Services to acquire end-to-end commercial payload services between the Earth and the lunar surface for the Science, Human Exploration and Operations, and the Space Technology Mission Directorates. The contractor will provide all activities necessary to safely integrate, accommodate, transport, and operate NASA payloads using contractor-provided assets, including launch vehicles, lunar lander spacecraft, lunar surface systems, Earth re-entry vehicles, and associated resources. I met with industry representatives at the Commercial Lunar Payload Services Industry Day on May 8 and was excited by the growing partnership between NASA and commercial companies. NASA's expanding Moon strategy seeks to harness the innovation of American space companies to build new lunar landers. This solicitation for payload delivery services is a sign of NASA's ongoing confidence in the ability of U.S. industry to meet the needs for delivery services in space. These early deliveries to the lunar surface will support stronger scientific and exploration mission activities for NASA, and empower commercial industry to show the Agency what they have to offer.

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, in-

cluding 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 fiscal year 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 fiscal year 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 fiscal year 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 fiscal year 2018, the Laser Communications Relay Demonstration project will deliver the completed mission payload to support a fiscal year 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 fiscal year 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.

NASA will 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 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 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 August of this year, which 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 decisionmaking, and improve the quality of life for citizens in the United States and humankind around the globe. NASA's fiscal year 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 (NEO) 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, and 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 launched on May 5, 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 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 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.

In the coming year, 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. 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 be joined by the James Webb Space Telescope. 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. As we have informed the Committee, based on recent information, NASA has undertaken an external independent assessment of the schedule and cost of the Webb mission.

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), launched on April 18, 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.

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 as early as June 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 Ll 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 sat-

ellites 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 decisionmaking 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, scheduled for launch on May 19) 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 fiscal year 2018 budget, the fiscal year 2019 budget proposes to terminate Plankton Aerosol Cloud ocean Ecosystem (PACE), 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 fiscal year 2019 budget invests in the most 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 that will demonstrate quiet overland supersonic flight and enable U.S. industry to open a new market. In fiscal year 2019, NASA will ensure the LBFD X-plane is on track for first flight by fiscal year 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 decisionmaking 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 fiscal year 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 fiscal year 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 Aero-

nautics Research Mission Directorate strategic outcomes, and who have proposed multi-disciplinary technical challenges, along with supporting activities to address those barriers.

EDUCATION

NASA's fiscal year 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 fiscal year 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 will 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 fiscal year 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's 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 fiscal year 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 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 fiscal year 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 subcommittee.

Senator MORAN. Mr. Secretary, before we turn to questions, let me encourage you to tell us, as part of your statement, the vision, the direction of NASA as reflected by its budget priorities. Outline for us what you see happening based upon the request of you and the administration for appropriations from our subcommittee.

Mr. BRIDENSTINE. Yes, Mr. Chairman. You are aware of Space Policy Directive 1, which is from the President of the United States directing us to return to the Moon and do it in a way that is sustainable for the long term. We have had in the past a number of different efforts to get back to the Moon since 1972, and in fact, we have been at the Moon and we still are at the Moon with orbiters and other capabilities. This President has said that getting back to the Moon with soft landings for the purpose of an eventual human return to the Moon is the objective to establish American leadership, but also to develop science capabilities on the Moon and utilize resources of the Moon—which is a new direction for this country, and I think it is an important direction—as we utilize the resources of the Moon to ultimately take us to Mars and beyond. That is, I think, a big policy direction shift.

I also want to be really clear that we are still going to Mars as well. In fact, one of my first launches as the Administrator was the InSight launch, which is a lander that right now is on its way to Mars. We are looking forward to doing a soft landing on Mars around the Thanksgiving timeframe and delivering science for an eventual human trip to Mars.

We are doing both. We are going to the Moon and we are going to Mars. We are not taking our eyes off the so many other critical, important missions of NASA, to include Earth Science, Heliophysics, Astrophysics, and Planetary Science with robotic landers and other things.

I would say one of the President's objectives—and we have seen this in the NASA Transition Authorization Act—is to seek constancy of purpose so as we go from one Administration to the next, as we are doing these decadal kind of missions, that we are actually moving out and accomplishing similar objectives to the previous Administration, but at the same time small shifts here and there to reflect the priorities of this President.

Senator MORAN. Thank you very much, Administrator. And thank you for joining us. I think this is your debut appearance as the Administrator of NASA in front of our committee, maybe in front of any congressional committee.

Mr. BRIDENSTINE. Yes, sir.

Senator MORAN. And I welcome you to your new position, and I thank you for working to develop a good working relationship with this subcommittee as we try to pursue things that make sense from a budget point of view but also advance a cause of science and space exploration. So thank you very much.

SCIENCE PORTFOLIO BALANCE

Let me ask you about that balance. Our committee has consistently looked at various scientific decadal studies that help us, guide us in making decisions in the process. Obviously, lots of budgetary

pressures always on any agency, but including NASA. How do you plan to maintain a balance in the scientific portfolio between planetary missions, Earth science, biophysics, and astrophysics? How do you reach the conclusion as to what the right ratio is of where our resources ought to go and what the mission of NASA should be?

Mr. BRIDENSTINE. That is a great question, Chairman, and it is not an easy question to answer. We have, of course, at NASA within the various divisions of the Science Mission Directorate, a lot of critically important science missions going forward from previous decadal surveys, as a matter of fact. What happens is when we take on some of these really big projects—and I can give a few examples, but one example that is very salient right now is the James Webb Space Telescope. We take on a project like that, which is something NASA needs to do. We need to be at the very leading edge of technology. We need to be pushing the edge of the envelope all the time. When we take on a big project like that with brand new technologies and brand new capabilities, we sometimes have overruns in schedule and in cost, and that starts to impact other parts of the Science Mission Directorate.

What we have to do going forward, as to your point, the balance that we need to have across the different divisions of the Science Mission Directorate, we need to look at historically how those kind of missions can sometimes potentially crowd out other missions and then build architectures that deliver that same civilization-changing science but maybe do it in a way where there is less risk involved.

One way to do that would be to look more at the missions that are safe, $200 million or less in lifecycle cost, and instead of doing one flagship mission, divide it up among a number of different missions. Then if one gets behind schedule or over cost, it does not impact all of the other missions that are currently underway. That is one way to develop architectures across the different divisions of the Science Mission Directorate that ultimately will not have such a massive impact on the balance of the portfolio within each one.

EDUCATION

Senator MORAN. Let me perhaps more make a statement, but maybe there is a question in this as well.

You and I visited in my office. One of the things that I think NASA provides that no other agency, no other Federal program can do is to inspire people and many times often young people, young men and women, to aspire to study science and mathematics and engineering and space. I have this goal from my own State at home in Kansas that we determine ways to increase STEM education. We need an inspiration, something that captures people's minds and hearts, and NASA in my view like no other agency or program can do so.

We talked about the budget request when you and I visited in person. And it eliminates a significant portion of that STEM education role for NASA, something that I indicated to you I find objectionable. You explained to me how this can be addressed in other ways. But I would ask you, I guess, again what is your vision and view for how NASA can help educate and inspire another gen-

eration of individuals interested in science and, in doing so, help our Nation economically, advance technology, and to make certain that we are at the forefront of all scientific and educational advancement globally. NASA in my view has that mission.

Mr. BRIDENSTINE. Yes, Chairman Moran. And I could not agree with your assessment on the importance of education more.

I will say this about my own life. I was a young boy in 6th grade, and I had the opportunity to go to a summer camp where I interacted with a wind tunnel for the first time. I learned about Bernoulli's theory of flight and how it works. I spent a week playing with the wind tunnel and changing the shape of a wing and seeing how that affected lift and drag and those kinds of things. That was I think the summer before my 6th grade year, and that impacted my life in an amazing way. From that point forward, I knew that when I grew up, I was going to be a pilot. It was just the way it was going to be. I have had that personal experience myself.

I can also tell you there was a time in my life when I was the director of the Tulsa Air and Space Museum, and I saw firsthand the impact that I had when I was a child. I saw that impact on other children as well, fundamentally changing the way they viewed themselves and what they wanted to be when they grew up and the things that they wanted to study. I can tell you this, there is no agency in the Federal Government that can do what NASA can do when it comes to inspiration, as you have mentioned.

Of course, I have spent time at your museum, the Cosmosphere in Hutchinson, Kansas, a wonderful, wonderful place. The scout troop that my son is a member of, we have gone up there and spent a weekend studying the history and the technology and the capabilities of NASA. I believe, as you believe, that is absolutely critical for our Nation.

I will tell you this, the 2018 Omnibus spending bill, which just got passed a few months ago, obviously funded the education budget of NASA. NASA right now is moving out to follow the requirements of that spending bill.

It is also true that we have had to make difficult decisions in challenging financial times, and this is one area that, of course, has been trimmed.

What I will tell you is that NASA has—and I have been there for a month now—NASA has in its DNA education, going back to the very beginning, and it has in its DNA inspiration. Every day NASA is making historical achievements, and every day, whether we want to or not, we are inspiring children and changing lives, and I will tell you that we want to. We are committed to it.

Going forward, each one of the mission directorates has the ability to affect education apart from that particular budget line, and we will continue to do that. In fact, just this week, we started an internship program with over 1,600 young folks that are coming to NASA to determine whether or not this is something they want to do for their futures. We are committed to education. We are committed to inspiration. I believe in it 100 percent, and of course, NASA will do that regardless of that particular budget line.

Senator MORAN. Administrator, thank you. I would point out that your budget was submitted prior to your confirmation, and

your budget was submitted prior to the fiscal year 2018 omnibus bill taking effect. So you start from a new plane. I do want to make sure that this is emphasized in our efforts.

And thank you for mentioning the Cosmosphere, and I look forward to your return visit to Kansas.

I now recognize the Ranking Member, Senator Schatz.

CLIMATE SCIENCE

Senator SCHATZ. Thank you, Mr. Chairman.

Administrator Bridenstine, thank you for being here.

Do you believe that greenhouse gases are the primary cause of climate change?

Mr. BRIDENSTINE. Yes. The National Climate Assessment that includes NASA—and it includes the Department of Energy and it includes NOAA—has clearly stated that it is extremely likely that human activity is the dominant cause of global warming, and I have no reason to doubt the science that comes from that.

Senator SCHATZ. Do you agree with the scientific consensus, which includes many NASA researchers, that the climate is changing and humans are the leading cause?

Mr. BRIDENSTINE. Yes.

Senator SCHATZ. Is it fair to call this an evolution of your views?

Mr. BRIDENSTINE. Yes.

Senator SCHATZ. Do you commit to supporting the funding, independence, and integrity of climate science at NASA?

Mr. BRIDENSTINE. Without question.

Senator SCHATZ. Thank you, Administrator Bridenstine. You and I have had multiple conversations, both over the table but since then, in person and on the phone. And I just want to recognize your evolution on this issue. I think it is essential for one of the premier science agencies of the Federal Government for you to abide by the science. I think it is especially important because, as you know, you are the first NASA Administrator that was an elected official. You are also the first NASA Administrator with an essentially partisan confirmation vote. And so we needed to move through this period of sort of ideological disagreement, political disagreement, and back to the point where the NASA Administrator is a leader of a science agency. And you cannot lead a science agency if you are not grounded by the science.

I thank you for that. I do not think it is easy for you to come to that conclusion. But on the other hand, what I have seen from you and in my interactions with you, I have come to the conclusion that this is a true evolution, that you respect the people with whom you work. You respect the science. You want their respect. And there is no way to move forward if you are going to be undermining the science. And so I am really pleased to see this change.

EARTH SCIENCE

I want to ask you about Earth science. NASA observations in Earth science support resource managers and policymakers. So I want to talk to you about the termination of the carbon monitoring grants that we have talked about, the $10 million worth of carbon monitoring grants.

First of all, I object to the termination of those grants. But second of all, I understand that NASA has numerous lines of efforts as it relates to carbon monitoring. So first, talk about the grants, and second, talk about your commitment to carbon monitoring and Earth Science generally.

Mr. BRIDENSTINE. Yes. Senator, when you think about the carbon cycle of the Earth, NASA has a number of different satellites currently that are taking into account how the Earth is changing and how our climate is changing and how carbon ultimately plays into that. Right now, we are spending over $100 million annually on measuring carbon not only in the atmosphere but on the surface of the Earth and in the oceans and other places. That is a critical piece of our Earth Science Division within the Science Mission Directorate.

The carbon monitoring system specifically was a grant program. It is $10 million every 3 years. About 8 months ago, we issued grants, and those grants are going to go through the year 2020. That program in the 2018 budget request was not put in the President's budget request, and it did not receive a line item in the appropriations process.

I will tell you that NASA has a number of programs even going forward. The Orbiting Carbon Observatory 2 is currently on orbit. The Orbiting Carbon Observatory 3 we are going to launch in January. GeoCarb is another satellite that we are developing and soon will be launching to monitor carbon. There is a satellite called ECOSTRESS that does similar things, and then GEDI is another satellite that we are launching.

So the bottom line, Senator, is NASA 100 percent committed to understanding the carbon cycle, which is an extremely high priority that comes from the decadal surveys of the National Academy of Sciences. You have my commitment that we are going to follow the guidance of those decadal surveys for the purpose of keeping it, as you have said, apolitical, bipartisan, nonpartisan because the science must not be partisan. NASA is not a regulating body. What we want to do is to get the data, and we want to make sure that we provide that data and that science to decision-makers who can ultimately make sure that we are doing the right things as a nation and leading the world. So you have my commitment that NASA will continue doing that kind of activity, and we are.

Senator SCHATZ. Thank you.

Senator MORAN. Senator Schatz, thank you.

Senator Capito.

Senator CAPITO. Thank you, Mr. Chairman.

Thank you, Mr. Administrator, for being here. I appreciate it. I know you waited a while to get here. So we are glad you are taking charge.

INDEPENDENT VERIFICATION AND VALIDATION

I wanted to ask you. You and I talked about the IV&V facility in Fairmont. I know that you have been aware and are supportive of that. I wanted to know what you might envision for the future there where the applications may be more beneficial to NASA but also within the Federal Government. If you have any thoughts on that.

Mr. BRIDENSTINE. Yes, ma'am. That is a wonderful question.

The IV&V facility is currently partnering with a number of different agencies apart from NASA. I can think of the Department of Energy, the Department of Homeland Security. Of course, we have some nongovernment partners as well. We do utilize NASA's IV&V facility to do governmental things that are broader than what NASA itself does. We want to continue doing that. We believe that we are a national asset that can be utilized by a whole host of different government and nongovernment functions. We want to make sure that when we do do that, though, we are not impacting, of course, NASA's missions. That is, I think, an important thing that I want to make sure that we do not impact NASA's missions, but certainly we see ourselves as a partner to the Federal Government at large.

Senator CAPITO. Thank you.

EDUCATION

Last week, NASA announced that a team from West Virginia University was selected to test their research in simulated microgravity at the Johnson Space Center. They will be able to conduct their experiments in the pool where the astronauts train for their space walks. This is a unique and tremendous opportunity for our students, as you can imagine. And it is part of NASA's education program.

So I continue to be frustrated that the administration continues to call for the elimination of NASA's Office of Education. So I would suggest maybe you rename it to be the Office of Inspiration because you are inspiring through these educational opportunities the next generation of science, technology, and interest in space, lighting a fire among a lot of young people.

Will you work with me to continue to emphasize the importance of inspiring that next generation? I did not know if you had any comments on the elimination of the Office of Education.

Mr. BRIDENSTINE. Yes, ma'am. We just had a long dialogue.

Senator CAPITO. Sorry.

Mr. BRIDENSTINE. No, you are good.

What is interesting is you mentioned renaming it the Office of Inspiration, and we have been moving in that direction at the NASA headquarters but calling it the Office of STEM Engagement. I think when we call it the Office of Education, people get this idea that we are duplicating services of maybe the Department of Education or other Federal entities.

What we do believe is that, as you are aware, NASA is unmatched in the Federal Government in its ability to inspire young folks and change lives and create the next generation of scientists and engineers. NASA is exceptionally unique in that.

In fact, you mentioned that you had folks—was it the University of West Virginia—that are heading down to Houston. The University of West Virginia has done amazing things with robotic return capabilities. All those technologies are eventually going to be used for a robotic return of material from the Martian surface. And if I remember right, the University of West Virginia won a massive prize, and this was done by your students. A prize. And of course,

that leads to more and greater technologies for that activity. It was about $750,000.

Senator CAPITO. That is correct. And they are working on—the West Virginia Robotic Technology Center is working on the Restore-L and working to refuel satellites in the low orbit.

Let me just say, since I just have less than a minute—and I think I shared this with when you when we talked. Trying to inspire the next generation of young women and particularly into the STEM area—I just want to thank NASA because Dr. Peggy Whitson came to two elementary schools with me, talked about her spacewalks, talks about how she has been in space longer than anybody else in history. And she really inspired a lot of young girls that day. That is such a rich resource. I mean, I was kind of standing there going does anybody want to get in public service, and nobody would even look at me because they were just crazy to listen to what is it like to be in space and to get to be up close and personal with such an inspirational figure. So I hope that program continues, and I hope that the resources that you have there you share with the next generation to inspire. So thank you for that.

Mr. BRIDENSTINE. Yes, ma'am. Thank you.

Senator MORAN. Senator Van Hollen.

Senator Van Hollen.

Senator VAN HOLLEN. Thank you, Mr. Chairman.

Administrator Bridenstine, welcome and congratulations, and I appreciated the chance to get together with you again yesterday and go over some issues. And I want to thank you for the tone that you have taken ever since you were sworn in, and I do want to just underscore the comments of my colleague, Senator Schatz, with respect to your commitment to follow the science. I think the employees at NASA appreciated the town hall meeting where you brought people together and committed to focusing on the mission. And I appreciate your enthusiasm and energy about the NASA mission, which is a great American success story and a success story for the world.

And I do want to also underscore, I think, the importance of sending the message that we will focus on real science not political science, including when it comes to recognizing that climate change is being driven primarily by carbon emissions generated by human activity. So I am glad we are all focused on the science.

And I also know that you were not responsible for the budget that was submitted. It was our former colleague in the House. We can all go talk to Mick Mulvaney at the Office of Management and Budget.

EARTH SCIENCE

But I do want to echo concerns that have been raised by all of our colleagues here on a bipartisan basis and specifically with respect to some significant cuts in the Earth sciences budget. I am very proud of the fact that Maryland is home to NASA Goddard, and we also share with the Virginia region, the Delaware region, Wallops Flight Facility.

But on Earth sciences—and you and I spoke about this yesterday—there are proposals to—really deep cuts, eliminate the PACE program and some other Earth sciences programs. So if you could

just again talk about what you see as the importance of those programs to the NASA mission.

Mr. BRIDENSTINE. Absolutely. A couple of things that I think are important to make sure because this is a bipartisan issue and I want to keep it as bipartisan as we can possibly keep it. It is important for our country. It is important for the world.

The President's budget request for 2019 on the Earth Science side of the ledger was higher than 3 of the previous Administration's budgets for Earth Science, and it is tied with a fourth. It is kind of right there in the middle historically of the last 9–10 years. I think it is a good budget. Obviously, making difficult decisions in tough times, we made a determination that there were a couple of programs that ultimately were not the highest priority.

It is absolutely important to me, as I know it is important to you, that NASA follows the guidance of the decadal survey. A brand new decadal survey came out in January of this year, and that decadal survey indicated that CLARREO and, as you mentioned, PACE are high priorities for the National Academy of Sciences that created the decadal survey.

That being the case, what we are doing right now within the Earth Science Division of the Science Mission Directorate is we are evaluating that decadal survey, trying to make sure that we are covering all the science that they have called for us to cover, and at the same time, because of what the Senate and the House did for the 2018 Omnibus, we are moving forward with those programs. You mentioned PACE. I mentioned CLARREO. Right now, we are currently moving forward with those programs as required by the Omnibus of 2018.

When we get to the point where we are ready to present how NASA sees the new decadal survey that recently came out, I will be more than happy to come and brief you and make sure that we are all in agreement that we are getting the science necessary that the National Academies have called for.

Senator VAN HOLLEN. I appreciate that. I will probably submit for the record—there are a number of other programs. Restore-L is one where NASA is sort of on a path-breaking mission for refueling, a number of other programs, including DSCOVR.

WALLOPS

But if I could just use the remainder of my time to talk about Wallops because I know you recently visited Wallops. If you could talk about why the Wallops Flight Facility is an important asset for NASA.

Mr. BRIDENSTINE. Absolutely. Just a few days ago, I was out there preceding a launch to the International Space Station from the Antares rocket and the Cygnus spacecraft that was resupplying the International Space Station. It is an amazing, critical, strategic asset for the United States of America. It helps us maintain our leadership in the world on the International Space Station with those critical resupply missions. Of course, there are a number of different sounding rockets that are launched from there for the purposes of weather research and climate research and a whole host of other capabilities.

It is also true that there are a number of aircraft out there, former Navy aircraft. There is a P–3 that is importantly using Lidar to measure how thick are the ice sheets in the Arctic or on the North Pole. In fact, just recently we had some amazingly brave pilots flying over the North Pole, flying over Greenland, over the north Atlantic, flying over Alaska measuring the thickness of the ice using Lidar, laser radar, if you will. The capabilities that are coming from that, of course, are informing—helping us understand how the cryosphere is changing, the ice on the surface of the planet and how that affects the rest of the planet. Those missions are important. We have NASA pilots that are taking great risk upon themselves to accomplish that science. All of that is being done from Wallops.

RESTORE-L

On the Restore-L, if I have some time, I would like to address that, if it is okay, Chairman.

Senator MORAN. Please.

Mr. BRIDENSTINE. This is important. Robotic servicing for our country is a critical capability that we need to have for whole host of strategic reasons. Very soon, a number of commercial satellite operators are going to be launching into low Earth orbit with thousands of satellites for communications. And historically, satellites, when they die, we either try to bring them out of orbit or we supersynch them, meaning we put them into a very deep orbit that gets them out of the way. If you are in geostationary orbit, we supersynch them. In low Earth orbit, we try to bring them out of orbit.

On top of all that, some satellites just do not work, and they die, and then they become orbital debris. We have had collisions, and we have had reports that indicate that an Iridium-Cosmos type collision that happened in 2009 that created 5,000 pieces of orbital debris—those kinds of collisions are going to continue to happen every 5 to 9 years.

We have to make sure we do not do that. Orbital servicing of satellites, robotic servicing, is a critical capability. NASA is committed to it, and we want to make sure that we are doing it in a way that we can very dynamically and robustly service satellites in low Earth orbit to mitigate the orbital debris problem, keep our satellites on orbit longer, and make use of that capability. You have a commitment from me that we will do that kind of activity.

Senator VAN HOLLEN. Thank you. I look forward to working with you.

Thank you, Mr. Chairman.

Senator MORAN. Thank you, Senator.

I am going to suggest a modified second round of questions. We have other Senators who are expected to arrive. We welcome the Senator from Alaska. But in the absence of a new arrival, those who are here or remain here will have additional questions until approximately 3:15 or so.

So I now recognize the Senator from Alaska, Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman. I appreciate it.

Administrator, nice to see you.

Mr. BRIDENSTINE. Thank you.

NON-FEDERAL SPACEPORTS

Senator MURKOWSKI. I think you bring a refreshing view of expanding commercial space operations to the fore here and look forward to having some conversations about what can be done to help lower costs, increase the capabilities for NASA by increasing some of the partnerships and utilizing more of the capabilities that are offered by the private sector for space access and operations.

We have in Alaska, as you know, some opportunities with the Pacific Spaceport Complex in Kodiak. It is operated by the Alaska Aerospace Corporation.

Can you share with me how you view the use or the potential of non-Federal spaceports that can provide both the orbital and suborbital launch capabilities that may fit into future NASA programs and operations?

Mr. BRIDENSTINE. Yes, Senator. NASA is committed to getting more science and more data than we have ever been able to get before, and we are able to do that now because there are commercial partners providing data in low Earth orbit, remote sensing and imagery, as well as communication. All kinds of different sensors are being launched commercially to provide all kinds of capabilities that really have nothing to do with NASA specifically.

What that means is that we have the ability as an Agency to purchase commercially access to space and to purchase commercially data from other people that are accessing space for other reasons.

The way I see it, ma'am, going forward is the miniaturization of electronics, the reusability of rockets—we are going to see unprecedented access to space in the coming years. A facility like Kodiak, of course, is going to be a beneficiary of that capability.

As an Agency, we are going to be launching commercially a whole host of small satellites to do science, and of course, even universities are building satellites on our behest. The more we do that kind of activity, the more data we are going to receive. What we do not do is, we do not tell our partners where to launch from, but a healthy small launch market, medium class launch market is what we want as a nation strategically beyond just NASA but for our Nation strategically. Of course, Kodiak could be a great player in that.

SMALL LAUNCH

Senator MURKOWSKI. Well, you mentioned there is a lot of potential. I think we recognize that there. So the small launch vehicle operators have some great opportunity I think to expand our space launch market and bring back some of that launch business that we have been seeing overseas. So hopefully, you share that same view of opportunity for how we might proceed with that.

Let me ask about your plans, if any, to work with Federal and non-Federal entities to help streamline the satellite regulations and the launches that would help provide an improved broadband infrastructure for rural areas. This is, of course, of great interest to us up in the north and particularly the high north. We see this as that opportunity that will really help build out our capacity in

some of these very remote, rural, and high-cost areas. Can you speak to that?

Mr. BRIDENSTINE. Absolutely, it would be my honor to speak to it.

Historically when you talk about communications from space, historically it has been done from geostationary orbit. When you think about DirecTV and Dish Network, even some communication satellites for Internet from space, for example, that is done from geostationary orbit, which is 33,000 kilometers from Earth. It is the highest orbit. The up side is that they do not move relative to the moving of the Earth. As the Earth turns, they stay in the same position over the Earth. That is the up side. The down side is that there is latency. There is a time for the signal to travel all the way out to geostationary orbit and all the way back.

What is happening now that I think a lot of us, and I know you are excited about, is the idea that we have got antennas now that are electronically steerable, which means a flat antenna like this notepad would be on somebody's house. In low Earth orbit, where the satellites are constantly coming over the horizon and you cannot just have your satellite dish locked to one satellite, you have got to be tracking one satellite and sharing information back and forth with that satellite. Other satellites are coming by. You have to be able to pick those up. Electronically steerable satellite antennas are a huge technology breakthrough that are now being commercialized, which enables us to do this. Take those satellites in geostationary orbit and bring them down to low Earth orbit.

Now, this is not necessarily tied to NASA, but it is tied to a robust commercial marketplace for communications to the point where if we can get it down to low Earth orbit, these constellations of thousands of satellites in low Earth orbit, the latency goes down to the point where you can use the exact same kind of waveforms as a cell phone. Now we have got potentially thousands of cell towers in low Earth orbit that any of us can access, and you can have portable bandwidth that can be—if there are 100,000 people descending on one part of the country—maybe there is a convention in Anchorage or something—you can steer the bandwidth to make sure that nobody gets blocked out from being able to use their cell phone.

This changes how we understand communications on planet Earth. I, for example, could be on an aircraft carrier, which I have been, in the middle of the Pacific Ocean with no access to any kind of Internet connectivity, and all of a sudden, if these kind of constellations get built, I would have access immediately, instantaneously. That is transformative. Obviously, in rural Alaska, that is a big game-changer.

Senator MURKOWSKI. Game-changer.

Mr. BRIDENSTINE. Absolutely a game-changer. It is a game-changer for a lot of my old constituents in Oklahoma, for example.

To what Senator Van Hollen was talking about with robotic servicing, that is the capability where satellites in low Earth orbit can be addressed with a robust commercial robotic servicing capability. Those satellites in low Earth orbit generally come out of orbit in 5 to 10 years just because there is trace atmosphere in those low Earth orbits. With robotic servicing, you can boost the satellites.

You can even change the technology on the satellites to increase capacity and throughput to get more data than we have ever gotten before, and, of course, data rates are continuing to increase. It is all about getting more gigabits per second of throughput.

There are a lot of opportunities here, and NASA wants to be a partner. That is why robotic servicing is so important, and we intend to do that.

Senator MURKOWSKI. Exciting.

Thank you, Mr. Chairman.

Senator MORAN. Thank you, Senator.

AERONAUTICS

Administrator, we talked about—a number of us raised the topic of education. Let me take this to the university level, but let me do that by talking a moment about the aeronautics aspect of NASA.

NASA, for example, is currently working on a low sonic boom aircraft that is expected to shorten flight times across the country and to destinations around the world. Research is done with the FAA on traffic management on integration of piloted and unpiloted vehicles into the Nation's airspace. Advanced material developments and characterization will lead to safer, cleaner, more fuel efficient aircraft. Kansas, as you know—Oklahoma as well—is in aircraft aviation. We are States—that in many ways dominates what we do for a living.

I want to know your view as to the role that universities can play in being a partner with NASA in regard to aeronautics. What do you expect to happen and how can I be of help to you in that regard?

Mr. BRIDENSTINE. That is another wonderful question. We see universities as a great opportunity to help us do the research necessary to get more advanced materials, composites, for example. I know you guys in Kansas are really big into composite repair and composite manufacturing. I know the Aeronautics Research Mission Directorate at NASA is working through an advanced composite program with, I think it is, the University of Wichita in conjunction with Spirit AeroSystems to put together a consortium of research, which is the university, and manufacturing, which is Spirit AeroSystems. That kind of partnership, along with some of our brilliant engineers, puts together really an ability for us to stay ahead technologically when it comes to manufacturing aircraft and creating lighter materials, materials that ultimately increase fuel efficiency and improve aviation in our country and make us more competitive in the world. I think that partnership is solid. I think we need to do more of that kind of activity, and I support it.

Senator MORAN. I appreciate your answer.

WEBB TELESCOPE

As I arrived in this position to Chair this subcommittee, one of the things that captured my attention and somewhat my imagination is the Webb telescope. And it has had its challenges. And I am interested in knowing what you see as its history, but more importantly, what you see as its future. There has been a lot of attention paid it by Congress, by GAO, by the contractor. What do you see

forthcoming despite some of the challenges that the telescope has had?

Mr. BRIDENSTINE. Yes, Chairman. It is a challenge that we have.

I want to start by saying this and I believe this. With James Webb Space Telescope and other things that NASA does, what we ought to be doing is staying at the very leading edge of technology. When the James Webb Space Telescope launches, it is going to see back to the beginning of the universe. That is an amazing capability that all of us are anxiously anticipating.

That being said, as important as that mission is, as critical as it is to NASA and to the United States and to the world, as critical as it is, it has had its challenges because we are at that very leading edge of technology.

There have been a number of challenges. You start with the fact that the thrusters were one of the issues that we had. The thrusters were cleaned with a solvent that was not the right solvent, and that damaged some of the seals that ultimately required us to go back and develop new thrusters, to build new thrusters, and fix thrusters. That set us back.

The sunshield that was on it, the ability to unfold it and fold it back together and test it—that has proven more challenging than I think was anticipated and that has set us back in terms of time and budget.

We are with our challenges with the James Webb Space Telescope.

I will tell you this: Looking at the budget for 2019, I do not think the impact is going to be that significant and here is why. Instead of doing operations, which we have a budget for operations for James Webb, we will just use that operations budget for development. That is not a good thing. I would rather be using it for operations, but the reality is for the 2019 budget, I do not think it will be that big of an impact. I do not think it will be that big of an impact for 2020 for that same reason.

The biggest challenge that I have, sir—and I am probably going to have to come back and talk to you—there is a potential—I do not want to get ahead of myself because I do not know yet, but there is a potential I might need to come back and talk to you. There is a funding limit on the James Webb Space Telescope that is set at $8 billion, and if the development costs go beyond that, we are going to have to come back to Congress and get reauthorized to continue the mission.

I would say that at this point, we have spent so much money and we have come so far and we are so close, that it is important that we do that. I will testify to that today, but I am here to tell you that I do not know if we are going to hit that $8 billion mark or not. I honestly do not know that.

The good thing is we have an independent review that is underway right now by a person who is exceptionally good at this kind of activity, and he and his team are going to report to us and to you on the status of the James Webb here in June. When that report comes out, we are going to have to come to a meeting of the minds and figure out how do we go forward with this program, if indeed we do need to go above the $8 billion cap that was set by Congress.

Senator MORAN. Thank you for your testimony.

Senator Van Hollen.

Senator VAN HOLLEN. Well, thank you, Mr. Chairman. I was just checking off one of my questions on the Webb telescope. And we talked about that when we met yesterday, Mr. Administrator.

Mr. BRIDENSTINE. Yes, sir.

Senator VAN HOLLEN. You are right. We have had some setbacks. I hope the independent review gets to the bottom of that. But as I understand your testimony, you are 100 percent committed to getting this program to completion and fulfilling the mission. Is that right?

Mr. BRIDENSTINE. Without question.

WFIRST

Senator VAN HOLLEN. The other question I had related to one of the recommendations that came out of the decadal survey. You mentioned the importance of pursuing the recommendations, and we talked about this a little bit yesterday. And the top priority, the large project in the 2010 National Research Council's decadal survey of astronomy and astrophysics was the wide field infrared survey telescope, WFIRST.

Could you just talk a little bit about why the decadal survey made that a priority and the importance of that mission?

Mr. BRIDENSTINE. Absolutely. When we think about these big projects like the James Webb Space Telescope and the WFIRST space telescope, these are opportunities for us—we are talking about programs that have a finite lifetime. When the end of the James Webb happens, we need to have something that can come next, and that something needs to push the edge just a little bit further than the previous. Now, I certainly understand all of that.

One of the challenges we have is because when we do these flagship programs that take a big chunk of what the decadal survey is wanting in terms of science, and if you take 60 percent of the budget that we have to do one particular mission and then that mission grows, that puts us in a really difficult spot for all of our other missions.

When we think about WFIRST, first of all, we are following through on the Omnibus of 2018. That is happening right now. We are looking at what the costs are going to be going forward for WFIRST, and we are committed to not have the same thing happen to WFIRST that happened to James Webb. That is where we are on that.

Going forward, when we think about decadal surveys in the future, we might want to consider maybe distributing the risk among more smaller projects rather than one massive project that can clobber an entire division within the NASA budget.

Senator VAN HOLLEN. Got it. Well, I look forward to continuing the conversation.

Thank you, Mr. Chairman.

Senator MORAN. Senator, thank you.

Senator Schatz, thanks for filling the role of ranking member today.

And, Administrator Bridenstine, thank you very much for your testimony. Our votes have been called. I would ask you, if you have

a moment after the hearing, I would like to spend a minute with you.

Mr. BRIDENSTINE. Yes, sir.

Senator MORAN. And I would announce that our subcommittee will have its markup at 2:30 on June the 12th. That will include NASA but our full array of issues within our subcommittee's jurisdiction. Two days later, June 14, the full committee is scheduled to meet to do markup of this and other appropriation bills.

ADDITIONAL COMMITTEE QUESTIONS

With that, there are no further questions this afternoon. Senators may submit additional questions for the subcommittee's official hearing record. We request that NASA respond to those questions within 30 days.

[The following questions were not asked at the hearing, but were submitted to the Agency for response subsequent to the hearing:]

QUESTIONS SUBMITTED TO HON. JAMES F. BRIDENSTINE

QUESTIONS SUBMITTED BY SENATOR JOHN BOOZMAN

Question. Administrator Bridenstine, thank you for testifying about the request for fiscal year 2019 funding for NASA. I appreciated the opportunity to talk to you in my office a couple weeks ago to discuss your plans for NASA and to hear you lay out the return to a focus on lunar and cislunar exploration. I certainly want to support that effort. In the omnibus for fiscal year 2018, we funded NASA at $20.8 billion, almost $2 billion above the President's budget request. I was pleased to see that the budget request this year was increased by $800 million over what the agency projected for fiscal year 2019 last year. Still, I think Congress will continue to show its strong support for your mission. In the budget request, I noted no funding was made available for the Experimental Program to Stimulate Competitive Research, or EPSCoR That, in fact, the proposal is to shut down the Office of Education that oversees EPSCoR and other grant programs. Arkansas scientists benefits from this NASA program via the Arkansas Space Grant Consortium. Your budget proposal indicates that STEM engagement will now be overseen by the Agency Management and Operations team.

How will you ensure that NASA continues its vital contributions to STEM education if this transition occurs?

Answer. While the fiscal year 2019 budget no longer supports the formal Office of Education programs, a common vision, mission and focus areas will drive NASA's future endeavors in STEM engagement and public engagement. The Agency Management and Operations budget will support ~13 civil servants for the Office of STEM Engagement, which will be accountable for strategic guidance and coordination of NASA's STEM engagement efforts Agency-wide, enabling a mission-driven approach to this work in close collaboration with the Mission Directorates.

Through its Mission Directorates, NASA will focus on creating unique opportunities for students and the public 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 public understanding by enabling powerful connections to NASA's mission and work.

Question. For programs, like the Arkansas Space Grant Consortium, that benefit from current NASA programs, how can they continue to be engaged with and supported by NASA?

Answer. While the fiscal year 2019 budget no longer supports the formal Office of Education programs such as the National Space Grant College and Fellowship Program, NASA will continue creating unique opportunities for students and the public to contribute to NASA's work in exploration and discovery through its Mission Directorates. NASA will also continue to offer internships and fellowships and work to build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content and facilities. There are also opportunities for organizations, like the Arkansas Space Grant Consortium, researchers, businesses and entrepreneurs throughout the country to engage with NASA

through a variety of solicitations and partnership opportunities typically posted here: https://nspires.nasaprs.com/external/

In addition, the following NASA mission directorates also provide opportunities that may interest Arkansas State:

—The HEOMD education initiatives are listed at: https://www.nasa.gov/directorates/heo/education/projects.html
—The SMD education initiatives are listed at: http://smdepo.org/projects
—The STMD education initiatives (through Glenn Research Center) are listed at: https://spaceflightsystems.grc.nasa.gov/education-outreach/
—The ARMD education initiatives are listed at: https://www.hq.nasa.gov/office/aero/education.htm

Also, NASA routinely conducts outreach events in areas where there is not a NASA presence or NASA Center. For example, NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STIR) program officials routinely take part in the Small Business Administration's SBIR Road Tours (https://www.sbir.gov/sbir-road-tour), which play an important role in increasing engagement with entrepreneurial ecosystems across the country to support the creation of small businesses focusing on next generation research. For example, Little Rock, Arkansas hosted a Road Tour at the University of Arkansas, Little Rock Reynolds Business Center on April 18, 2018.

Organizations may also request the NASA Office of Small Business Programs to participate in outreach events being held in their States to discuss how to do business with NASA. For example, NASA collaborates with local Procurement Technical Assistance Centers (PTAC) organizations to promote NASA community-level events. At these events, local industry can get more information about NASA small business programs, the SBIR/STTR program, the NASA Centers, and NASA prime contractors.

NASA hosts webinars covering different topics to help industry better understand how to work with the Agency and our prime contractors. NASA also has several websites that individuals or industry can access to get more information (including contact details). For example, the SBIR/STTR program (https://sbir.nasa.gov/), and Small Business Programs (https://www.osbp.nasa.gov/).

Question. Can you assure me that my schools in Arkansas will continue to enjoy a productive relationship with your Agency?

Answer. We will continue to engage the Nation in NASA's mission. While NASA cannot assure continuance of specific relationships with existing programs that are funded by the Office of Education, we can however ensure that the agency will continue to provide opportunities that include immersing the public in NASA's work in air and space, enhancing STEM literacy, and inspiring the next generation to pursue STEM.

QUESTIONS SUBMITTED BY SENATOR JOHN KENNEDY

Question. With the rise of private space firms such as SpaceX and Virgin Galactic, we have seen affordability and reusability become important factors in the space arena. Are there any cost saving lessons that NASA can adapt from the private space industry?

Answer. The President's fiscal year 2019 budget request proposes an integrated, Agency-wide Exploration Campaign, which will be executed with the goals of establishing an innovative and sustainable program of exploration in concert with our commercial and international partners. NASA plans to develop key technologies needed to make exploration more capable and cost-effective and develop spaceflight interoperability standards to increase competitiveness and opportunities for new partners. The Agency will leverage its unique capabilities, as well as those of the private sector, and use partnerships to develop safe, reliable, and cost-effective space systems, while simultaneously developing a commercial low-Earth orbit (LEO) space economy. NASA is planning acquisition strategies that leverage existing commercial designs rather then creating new designs to lower overall development and sustaining costs. NASA is also working on spaceflight acquisition approaches such as Gateway that will enable partnerships to achieve the goals of both partners while furthering exploration capabilities. The Agency's long-term Mars plans include reuse of transportation and habitation systems through cislunar points of departure and return, avoiding the costs of propellant systems necessary to leave and return in the Earth's strong gravity well. Finally, the Agency is assessing lunar lander concepts and low lunar orbiting tugs that are refuellable and reusable for multiple missions.

Question. In March, the President announced his 'America First National Space Strategy'. In his announcement the President stated that our international rivals

have turned space into a warfighting domain. How can we better prepare our space infrastructure for attacks from international adversaries and bad actors?

Answer. As context, NASA's perspective on the space domain has been from a mission-based civil architecture rather than from the extensive systems planning inherent in mission-driven military capability for warfighting and survivability.

The need for protection of NASA's space infrastructure, or more broadly the NASA enterprise, begins with understanding the risks and potential threats to space assets and to the overall enterprise. Once a risk is identified, a posture for protection of infrastructure and enterprise systems could span a wide range of assets and capability.

For example, within NASA, space systems span capability from human spaceflight to robotic science spacecraft performing roles that may deliver a capability over decades. In all NASA missions there are critical ground-based operations and communications systems upon which there is a dependency for safe operation of the space operations architecture. Additionally, there are corporate information systems that tie legacy and new mission ground-based infrastructure supporting core NASA missions in space flight, as well as research and development, test facilities and equipment.

NASA has been aware of evolving competitive sophistication in the space domain which drives the need for identifying vulnerabilities and risks associated with maintaining mission-assured civil capability from adversarial attack. We have implemented a program of identifying, classifying and assessing applicable threats, followed by implementing risk mitigations to reduce exposure. In practice, as we continue to implement mitigations and strengthen our posture toward protection of our enterprise systems, additional investments will likely be required to perform core NASA missions in a rapidly evolving space domain.

Question. With the first SLS mission scheduled for 2020, do you have an updated budget forecast for the SLS program that you can share?

Answer. The current Space Launch System (SLS) runout is reflected in the fiscal year 2019 President's budget request, as below; any changes in the runout will be reflected in future budget requests.

BUDGET AUTHORITY

[In millions of dollars]

	2019	2020 *	2021 *	2022 *	2023 *
Space Launch System	2,078.1	2,062.9	2,165.1	2,131.0	2,276.0

* Notional

SUBCOMMITTEE RECESS

The subcommittee now stands in recess, subject to the call of the chair.

[Whereupon, at 3:18 p.m., Wednesday, May 23, the subcommittee was recessed, to reconvene subject to the call of the Chair.]