A REVIEW OF THE NASA FISCAL YEAR 2020 BUDGET REQUEST

HEARING

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTEENTH CONGRESS

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April 2, 2019

A REVIEW OF THE NASA FISCAL YEAR 2020 BUDGET REQUEST

TUESDAY, APRIL 2, 2019

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Committee met, pursuant to notice, at 10 a.m., in room 2318 of the Rayburn House Office Building, Hon. Eddie Bernice Johnson [Chairwoman of the Committee] presiding.

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER

"A Review of the NASA Fiscal Year 2020 Budget Request"

Tuesday, April 2, 2019
10:00 a.m.
2318 Rayburn House Office Building

PURPOSE

On Tuesday, April 2, 2019 at 10:00 a.m., the Committee on Science, Space, and Technology will hold a Full Committee hearing titled *"A Review of the NASA Fiscal Year 2020 Budget Request."* The purpose of the hearing is to review the Administration's FY 2020 budget request and associated issues for the National Aeronautics and Space Administration (NASA).

WITNESS

- **Mr. James F. Bridenstine,** Administrator, National Aeronautics and Space Administration

BACKGROUND

The Trump Administration submitted its request of $21.019 billion for the NASA for Fiscal Year (FY) 2020. The proposal is $481 million or about 2 percent lower than the FY 2019 enacted appropriation. The FY 2020 request includes a focus on robotic and human exploration of the Moon; $10.7 billion of the top-line request is for exploration-related activities, including the goal to send humans to the surface of the Moon by 2028. The request also proposes reorganization of programmatic content. Space technology, which was organized as a cross-cutting technology program supporting Science and Exploration, would be funded under an Exploration Technology account and would focus, significantly, on exploration-related technology activities.

On March 26, 2019, just two weeks after the release of the FY 2020 budget proposal, Vice President Pence, at a meeting of the National Space Council in Huntsville, AL, announced an accelerated schedule for a human landing on the Moon from 2028 to 2024. The Administration has not yet stated whether or not it will request additional funding for the 5-year Moon landing.

Overarching Questions

- *Does the FY 2020 budget proposal support getting humans safely to the Moon by 2024 as the Vice President announced, or even 2028 as the budget request proposes? How much*

additional funding would be needed to accelerate a human Moon landing, and when would it be required?

- *What impacts would the proposed Moon program have on the other missions of NASA—science, aeronautics, space technology—and the balance among those missions?*
- *Does the budget proposal support a consistent plan for NASA, especially NASA's human exploration program?*

Deep Space Exploration Systems

The Administration's FY 2020 request proposes $5.021 billion, a $30 million or about a .6 percent decrease, for Deep Space Exploration Systems, which includes 1) Exploration Systems Development --Space Launch System (SLS), Orion, and Exploration Ground Systems (EGS)—the key launch and ground capabilities to support deep space exploration, and 2) Exploration Research and Technology, which focuses on technologies and systems developments required for cislunar and lunar surface activities.

Within the Deep Space Exploration Systems account, the request for *Exploration Systems* is $3.44 billion, a $650 million or about a 16 percent decrease from the FY 2019 enacted level. Specifically, the request would cut SLS by $375 million, cut Orion by $84 million, and does not including funding for development of an Exploration Upper Stage or a second Mobile Launch Platform, which would support a higher lift capability to low-Earth orbit and cislunar space.

The Administration is requesting $1.58 billion, a $622 million or 65 percent increase, over the FY 2019 enacted appropriation for *Exploration Research and Development*, which would fund four major areas: 1) Advanced Exploration Systems, which supports the development and demonstration of exploration capabilities such as habitats and space suits; 2) Advanced Cislunar and Surface Capabilities, which would support a series of lunar missions on the lunar surface leading to the landing of humans on the Moon in 2028; 3) the Lunar Gateway, a station that orbits the Moon and serves as a platform to support human and robotic missions to the lunar surface; and the 4) Human Research Program, which supports research to understand and mitigate the risks of human health and performance in space.

The FY 2020 request would increase Advanced Cislunar Systems and Surface Capabilities by $247 million from the FY 2019 request and the Gateway by $317 million from the FY 2019 request.

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Exploration Systems Development	4395.0	4092.8	3441.7	3441.0	3468.4	3788.5	3654.7
Exploration Research & Development	395.0	958.0	1580.0	1854.5	2013.0	2850.4	3387.6
Total Budget	**4790.0**	**5050.8**	**5021.7**	**5295.5**	**5481.4**	**6639.0**	**7042.3**

Exploration Technology

The Administration is requesting $1 billion for Exploration Technology, about a 9 percent increase over the FY 2019 enacted appropriation. For FY 2020, the Exploration Technology would incorporate cross-cutting technology activities that were previously funded under the Space Technology program; however, the overall Exploration Technology account would be focused on technology development for lunar surface activities.

The account is organized into three lines: Early Stage Innovation and Partnerships, which includes early stage research and development supports academia, industry, and NASA entities on far-reaching technology activities; Technology Maturation, which includes efforts to bring technologies from a proof of concept to a more mature stage that is not yet ready for flight demonstration; and Technology Demonstration, which includes ground-based tests and flight demonstrations that validate the technologies for programmatic use by NASA or other Federal agencies and industry. Exploration Technology also manages SBIR and STTR awards.

The request includes a new Lunar Surface Innovation Initiative, which would facilitate the technology readiness of systems focused on lunar surface demonstrations over the next five years, such as in situ resource utilization and nuclear surface power.

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Early Stage Innovation and Partnerships	91.9	--	**123.4**	118.0	123.0	118.0	123.0
Technology Maturation	151.5	--	**282.5**	227.2	250.3	246.7	328.0
Technology Demonstration	321.7	--	**397.5**	411.8	391.4	362.3	231.2
SBIR and STTR	194.8	--	**210.8**	219.1	230.8	237.5	261.0
Total Budget	**760.0**	**926.9**	**1014.3**	**976.1**	**995.4**	**964.4**	**943.1**

LEO and Spaceflight Operations

The request for Low Earth Orbit (LEO) and Spaceflight Operations is $4.2857 billion, approximately 7.6 percent below the FY 2019 enacted appropriation. The account includes funding for the International Space Station (ISS) and crew and cargo transportation to and from the ISS.

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
International Space Station	1493.0	--	**1458.2**	1448.5	1449.4	1352.6	1315.7
Space Transportation	2345.8	--	**1828.6**	1854.1	1814.5	1746.2	1727.2
Space and Flight Support (SFS)	910.3	--	**848.9**	891.9	905.7	911.8	914.5
Commercial LEO Development	0.0	--	**150.0**	175.0	200.0	225.0	225.0
Total Budget	**4749.2**	**4639.1**	**4285.7**	**4369.5**	**4369.5**	**4235.5**	**4182.3**

International Space Station (ISS). The Administration is requesting $1.458 billion, a decrease of about 2.3 percent from the actual FY 2018 spending, to operate and conduct research on the ISS.

NASA intends to transition its role as an owner and operator of the ISS to a customer of a commercial operator of the ISS or a commercial LEO platform and end by 2025. The ISS budget request line also supports ISS Research, which includes technology development; basic and applied research in physical, chemical, and biological sciences; and Earth imaging and remote sensing. The request includes a 6 percent ($23 million) decrease from the actual FY 2018 spending on the ISS Research program, the most recent funding comparison.

Space Transportation. The request includes $1.8286 billion for Space Transportation, about a 22 percent decrease from the FY 2018 actual spending level. The account includes the Commercial Crew and Cargo Program, which funds operational commercial cargo resupply missions and the Russian Roscosmos State Corporation (Roscosmos) seats to transport crew to and from the ISS and the Commercial Crew Program (CCP), which facilitates the development of commercial crew transportation to and from the ISS. The decrease in the request accounts for the planned ramp down of the CCP expenditures as the industry partners approach operational status.

Space and Flight Support. The Administration is requesting $848.9 million for Space and Flight Support, a decrease of about 7 percent from the FY 2018 actual spending level. Space and Flight Support programs provide mission critical space communications, launch and test services, and astronaut training in service of both NASA and external customer missions. In FY 2020, NASA proposes establishing a new Communications Services Program to establish a path to transition NASA's LEO communication program to a future architecture based on a mix of commercial services and capabilities.

Commercial LEO Development. The Administration is again requesting $150 million for a new, focused, TBD effort to develop a commercial space economy in LEO, particularly focused on the transition from NASA's operation of the ISS to an environment in which NASA is one of many customers of a non-governmentally operated ISS or a commercial space station.

Science

The request for the Science Mission Directorate (SMD) is $6.3037 billion, about a 9 percent decrease from the FY 2019 enacted appropriation. According to the Congressional Budget Justification document, SMD programs "*focus on three interdisciplinary objectives: discovering the secrets of the Universe, searching for life in the Solar System and beyond, [and] protecting and improving life on Earth.*" SMD includes four divisions: Earth Science, Planetary Science, Astrophysics, and Heliophysics, which is the study of the Sun and the Earth-Sun environment.

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Earth Science	1921.0	--	**1779.8**	1785.6	1779.7	1666.5	1674.6
Planetary Science	2217.9	--	**2622.1**	2577.3	2629.4	2402.4	2350.9
Astrophysics	850.4	--	**844.8**	902.4	965.2	913.5	907.7
James Webb Space Telescope	533.7	375.1	**352.6**	415.1	175.4	172.0	172.0
Heliophysics	688.5	--	**704.5**	638.6	769.3	692.0	709.8
Total Budget	**6211.5**	**6905.7**	**6303.7**	**6319.0**	**6319.0**	**5846.5**	**5815.0**

Earth Science. The Administration is requesting $1.78 billion for Earth Science, about a 7 percent decrease from the FY 2019 enacted appropriation. The request would cancel two mission developments: the Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE) mission and the Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder mission.

The Earth Science account supports research and missions – both airborne and space-based – that contribute to our scientific understanding of Earth and its response to natural or human-induced changes. The division partners with other federal agencies to provide measurements that inform weather and climate predictions, resource management, natural disaster response, and environmental policy.

Planetary Science. The President's FY 2020 budget requests $2.62 billion for its Planetary Science Division, a decrease of 4.6 percent from the FY 2019 enacted budget. The request would support a flagship Mars Rover 2020 launch in July 2020 and launch of a Europa Clipper flagship mission in 2023, but recommends a commercially procured launch vehicle for Clipper instead of NASA's SLS. The proposal does not fund the Europa lander mission, citing cost and the recommendation of the National Academy of Sciences' Planetary Science decadal survey midterm assessment to prioritize the lander in the next decadal. The request also includes funding for a medium-size (New Frontiers) mission as well as initiation of a Mars Sample Return mission for launch as early as 2026. Planetary Science also funds the identification, characterization, and possible mitigation of asteroids and comets that are potentially hazardous to Earth.

Astrophysics. The Administration's FY 2020 budget request for the Astrophysics Division is $845 million, a 29 percent decrease from the FY 2019 enacted budget. The proposal, like the FY 2019 request, seeks to cancel the Wide-Field Infrared Survey Telescope (WFIRST), currently in development. The budget request would also fund medium-class and small competitively-selected missions.

James Webb Space Telescope (JWST). The Administration is requesting $352.6 million for the development of JWST, which accommodates the total development cost ($8.8 billion) and new launch date (March 2021) pursuant to Independent Review Board recommendations to NASA and approved in the FY 2019 appropriations. JWST is managed as a standalone project separate from the Astrophysics Division.

Heliophysics. The Administration is requesting $704.5 million for Heliophysics, about a 2 percent decrease from the FY 2019 enacted appropriation. The Heliophysics Division supports efforts to improve our understanding of the Sun, the Sun-Earth connection and its implication for life on Earth, and the Sun's interaction with the rest of the Solar System and beyond. The request includes an increase for development of the next Solar Terrestrial Probe (decadal-prioritized Interstellar Mapping and Acceleration Probe) and an anticipated award of new competitively-selected missions. The request also includes $15 million to support NASA's role in inter-agency space weather research-to-operations and operations-to-research efforts.

Aeronautics

The Aeronautics Research Mission Directorate's (ARMD) FY 2020 budget request from the Administration is $667 million, an 8 percent decrease from the enacted FY 2019 budget. The decrease is attributed to a transfer of aeroscience capabilities, including the Aeronautics Evaluation & Testing Capability Project (AETC), into a single project within the Safety, Security, and Mission Service account.

ARMD supports four key Programs: the *Airspace Operations and Safety Program*, which focuses research on the safe and efficient growth of global operations, the *Advanced Air Vehicles Program*, which conducts research on ultra-efficient vehicles, the *Integrated Aviation Systems Program*, which carries out integrated system-level research and technology, and the *Transformative Aero Concepts Program*, which supports hi-risk research across multiple strategic thrust areas for ARMD.

The FY 2020 request supports continuation of the Low Boom Flight Demonstrator Project, which supports development of an experimental aircraft (x-plane) to test new design approaches and community responses to supersonic overland flight. Data from the test is required, if regulatory changes are made to allow commercial supersonic flight. The request would also support testing and integration of electric propulsion components and systems, an Advanced Air Mobility Project for urban air mobility that will move both people and packages, fundamental research on hypersonics, and the safe integration of the rapidly increasing number of autonomous aircraft into the National Airspace System.

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Airspace Operations and Safety Program	118.7	--	121.2	130.6	133.5	136.2	138.9
Advanced Air Vehicles Program	237.7	--	188.1	203.3	212.2	219.3	224.2
Integrated Aviation Systems Program	221.5	--	233.2	209.4	202.2	97.1	87.2
Transformative Aero Concepts Program	112.2	--	124.4	130.3	132.3	134.6	136.7
Total Budget	**690.0**	**725.0**	**666.9**	**673.6**	**680.3**	**587.1**	**587.0**

STEM Engagement

The FY 2020 Budget proposes the termination of NASA's Office of STEM Engagement, which was appropriated $110 million in FY 2019. The Office of STEM Engagement supports programs focused on attracting young people to STEM, including the National Space Grant and Fellowship Program, the Established Program to Stimulate Competitive Research (EPSCoR), and the Minority University Research and Education Project (MUREP).

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Total Budget	**100.0**	**110.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Safety, Security, and Mission Services

The Administration is requesting $3 billion for Safety, Security, and Mission Services (SSMS), a 12 percent increase over the FY 2019 enacted appropriation. Within the SSMS account, the *Center Management and Operations* budget funds ongoing management, operations, and maintenance at centers and component facilities. The *Agency Management and Operations* budget provides management and oversight of Agency missions and performance of NASA-wide mission support activities and also supports Safety and Mission success.

The SSMS request includes an increase in facility maintenance activities to help reduce the current backlog of facility maintenance projects and requirements associated with an aging infrastructure.

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Center Management and Operations	1983.4	--	2065.0	2058.4	2052.9	1906.0	1905.8
Agency Management and Operations	843.5	--	1019.6	1026.2	1031.7	965.6	965.8
Total Budget	**2826.9**	**2755.0**	**3084.6**	**3084.6**	**3084.6**	**2871.6**	**2871.6**

Construction and Environmental Compliance and Restoration

The Administration is requesting $600 million for Construction and Environmental Compliance and Restoration (CECR), a 72 percent increase over the FY 2019 enacted appropriation. The CECR account funds facility design and construction, demolition projects, and environmental compliance and restoration activities. The FY 2020 request includes increased funding for repair of obsolete and deteriorated systems, which will reduce mission and safety risk. The request including funding for two Construction of Facilities projects: The Flight Electronics Integration Facility at the Jet Propulsion Laboratory and The Flight Dynamics Research Facility at Langley Research Center.

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Construction of Facilities	483.1	--	517.5	385.9	385.9	385.9	304.9
Environmental Compliance and Restoration	86.4	--	82.9	82.9	82.9	82.9	82.9
Total Budget	**569.5**	**348.2**	**600.4**	**468.8**	**468.8**	**468.8**	**387.8**

Inspector General

The Administration is requesting $41 million for the Office of the Inspector General (OIG), about a 6 percent increase over the FY 2019 enacted appropriations. The increase would support salary and benefits adjustments to ensure sufficient staffing to carry out OIG activities.

Budget Authority (in $ millions)	Actual FY 2018	Enacted FY 2019	Request FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
Total Budget	**39.0**	**39.3**	**41.7**	**42.1**	**42.5**	**43.0**	**43.4**

Chairwoman JOHNSON. The hearing will come to order. And without objection, the Chair is authorized to declare a recess at any time.

I know there are many hearings going on, so hopefully we will gain more people as the time passes.

Let me welcome Administrator Bridenstine, and we have a lot to cover at today's hearing, so I will come right to the point.

You have stated that NASA's (National Aeronautics and Space Administration's) Fiscal Year 2020 budget request is a good one, apparently in part because the President didn't cut your budget as much as he is proposing to cut the rest of America's Federal R&D (research and development) investments, and we consider rather misguided and harmful cuts to DOE (Department of Energy) and NSF's (National Science Foundation's) research budgets, so I'm really not that persuaded. In fact, I find both the NASA budget request and your written testimony for today's hearing to be a little disappointing.

The President's budget request for Fiscal Year 2020 proposes the same ill-advised cuts to important NASA science and education initiatives that it did last year, cuts which Congress has already considered and rejected in Fiscal Year 2019 *Appropriations Act*. Eliminating NASA's key STEM (science, technology, engineering, and mathematics) activities—the MUREP (Minority University Research and Education Project), Space Grant, and EPSCoR (Established Program to Stimulate Competitive Research), the highest-ranking astrophysics decadal priority the WFIRST (Wide Field Infrared Survey Telescope), and two critical Earth science missions PACE (Plankton, Aerosol, Cloud, Ocean Ecosystem) and CLARREO (Climate Absolute Radiance and Refractivity Observatory)—made no sense last year and we think it doesn't make any sense this year. I have little doubt these cuts will be rejected by the Congress again.

Yet it is in the area of human space flight, which accounts for half of NASA's budget, that I find your written testimony most troubling and nonresponsive. Relying on that testimony, I would have no idea that Vice President Pence, presumably speaking for the President, last week directed NASA to undertake a crash program to put astronauts on the moon within 5 years "by any means necessary," to quote the Vice President.

And what is the most justification for this crash program? To quote the Vice President again, it is because "we are in a space race today, just as we were in the 1960s, and the stakes are even higher." Moreover, according to the Vice President, the Chinese have "revealed their ambition to seize the lunar strategic high ground," whatever that means.

The simple truth is is that we are not in a space race to get to the moon. We won that race a half-century ago, as this year's commemoration of Apollo 11 makes clear. And using outdated cold war rhetoric about the adversary seizing the lunar strategic high ground only begs the question of why, if that is the Vice President's fear, the Department of Defense—with its more than $700 billion budget request—doesn't seem to share that fear and isn't tasked with preventing it from coming to pass.

However, rhetoric isn't the same as a credible plan, and this Committee needs to see if there is any substance to this crash program. The Vice President's directive to NASA came just 2 weeks after the Trump Administration submitted its NASA budget request to Congress. Moreover, it is to be completed within the same 5-year budget horizon that is contained in the President's Fiscal Year 2020 budget request.

Given the absence of an urgent crisis, it would be the height of irresponsibility for the Vice President of the United States to direct NASA to land astronauts on the moon within the next 5 years without knowing what it will cost, how achievable the schedule is, and how it would impact NASA's other programs. I expect, Mr. Administrator, for you to provide us this information today before this Committee, as I assume you provided to the White House on each of those questions in advance of the Vice President's speech.

The Committee needs to know how much money will be needed in each of the next 5 years to carry out the crash program. We need to know how much—if any—money the President proposes to add to NASA's budget over the next 5 years and the extent to which NASA's other programs will be cannibalized or cut to fund this initiative. We need to know if our international partners will be part of it or simply frozen out, as some of the rhetoric would seem to suggest. We need to know if the International Space Station will have to be shut down within the next few years to free up funding for the lunar crash program. In short, we need specifics, not rhetoric because rhetoric that is not backed by a concrete plan and believable cost estimates is just hot air. And hot air might be helpful in ballooning, but it won't get us to the moon or Mars.

Mr. Bridenstine, I, like many of my colleagues on this Committee, strongly support NASA, and we want our Nation to achieve challenging exploration goals like landing humans on Mars. If the moon is a useful and necessary waypoint on the way to Mars, then I believe Congress will support a sustainable exploration program that includes the moon. But NASA has to date provided no meaningful roadmap to Mars, despite congressional direction to do so.

And if you're not able to provide us with credible specifics at today's hearing, I think a great disservice is being done to the hardworking and dedicated men and women of NASA. They need programs and funding plans that are sustainable and inspiring, not a constantly shifting set of directives. I can assure you that this Committee will do its part to ensure that NASA can continue to be the inspiring leader in space exploration, science and technology, and aeronautics that it has been for the past 6 decades, and this hearing is just our first step.

So I thank you for being here. I know you've read many of the news clippings that we have read questioning what the plan really is for NASA, and I hope that we can get some answers.

[The prepared statement of Chairwoman Johnson follows:]

U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY

Opening Statement

Chairwoman Eddie Bernice Johnson (D-TX)

Full Committee Hearing:
A Review of the NASA Fiscal Year 2020 Budget Request
April 2, 2019

Good morning, and welcome Administrator Bridenstine.

We have a lot to cover at today's hearing, so I will come right to the point. You have stated that NASA's fiscal year 2020 budget request is a good one, apparently in part because the President didn't cut your budget as much as he is proposing to cut the rest of America's federal R&D investments, including misguided and harmful cuts to DOE's and NSF's research budgets.

I am not persuaded. In fact, I find both this NASA budget request and your written testimony for today's hearing to be disappointing and inadequate.

The President's budget request for FY 2020 proposes the same ill-advised cuts to important NASA science and education initiatives that it did last year—cuts which Congress has already considered and rejected in the FY 2019 appropriations act. Eliminating NASA's key STEM activities—MUREP, Space Grant, and EPSCoR, the highest ranked astrophysics decadal priority—WFIRST, and two critical Earth Science missions—PACE and CLARREO, made no sense last year and they make no sense this year. I have little doubt that those cuts will be rejected by Congress once again.

Yet it is in the area of human space flight, which accounts for half of NASA's budget, that I find your written testimony most troubling and non-responsive. Relying on that testimony, I would have no idea that Vice President Pence, presumably speaking for the President, last week directed NASA to undertake a crash program to put astronauts on the Moon within five years "by any means necessary", to quote the Vice President.

And what is the justification for this crash program? To quote the Vice President again, it's because "we're in a space race today, just as we were in the 1960s, and the stakes are even higher". Moreover, according to the Vice President, the Chinese have "revealed their ambition to seize the lunar strategic high ground", whatever that means. The simple truth is that we are not in a space race to get to the Moon. We won that race a half-century ago, as this year's commemoration of Apollo 11 makes clear. And using outdated Cold War rhetoric about an adversary seizing the lunar strategic high ground only begs the question of why if that is the Vice President's fear, the Department of Defense with its more than $700 billion budget request, doesn't seem to share that fear and isn't tasked with preventing it from coming to pass.

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And if you are not able to provide us with credible specifics at today's hearing, I think a great disservice is being done to the hardworking and dedicated men and women at NASA. They need programs and funding plans that are sustainable and inspiring, not a constantly shifting set of directives. I can assure you that this Committee will do its part to ensure that NASA can continue to be the inspiring leader in space exploration, science and technology, and aeronautics that it has been for the past six decades, and this hearing is just the first step.

Thank you, and I now yield to my friend and colleague, Ranking Member Lucas.

Chairwoman JOHNSON. If there are Members who wish to submit additional opening statements, you may do so later, but I now recognize Mr. Lucas for his opening remarks.

Mr. LUCAS. Thank you, Madam Chairman.

Our Nation's space program is a source of pride. It exemplifies the greatest aspects of our country: The pursuit of knowledge, heroism, technical excellence, perseverance, and the intrepid spirit to chart a course into the unknown. Exploration is in our DNA, and no other nation embraces that gift more than the United States.

The Trump Administration has harnessed our spirit of exploration and proposed to focus our efforts to pioneer space. By maintaining consistency for major programs like the Space Launch System (SLS), Orion, and Commercial Crew, the Administration is ensuring that our national goals to explore the moon, Mars, and beyond will be achieved rather than delayed. This consistency of purpose has also been demonstrated in this Administration's funding request.

At first glance, the President's FY2020 budget request appears to propose a reduction from the FY2019 enacted appropriation. However, that does not tell the whole story. Year after year, the Trump Administration has proposed increased funding for NASA only to have Congress appropriate even more than requested. For context, the current request calls for more than $21 billion, while the previous Administrations proposed a notional, nominal budget of just under $20 billion for FY2020. This Administration has added over $1 billion to NASA's budget request, and that's before Congress appropriates final funding.

This is a blessing and a curse. As many watching this hearing have heard before, "no bucks, no Buck Rogers." You have to remember the comic strip to appreciate that, but believe me. NASA is getting the bucks; now it's time to deliver. Too often programs become complacent when funding is taken for granted. Congress and NASA need to work to be good stewards of the taxpayers' dollars. We need to ensure these programs stay on schedule and within cost. Congress, along with the reconstituted National Space Council, led by Vice President Pence, provide this oversight.

Last year, the Space Council directed NASA to study efforts to fly crew on the first SLS mission. More recently, they reviewed ways to accelerate the Exploration Mission 1. Last week, the Space Council met to review the current status of our exploration program. The Vice President challenged the Nation to return astronauts to the moon by 2024. The current budget request that we are evaluating today does not enable that goal. I look forward to NASA updating their request so this Committee can review those details.

Aside from the budgetary unknowns, we do have a robust proposal on how we can achieve lunar exploration by 2024. The proposal focuses on the development of technologies that enable future exploration rather than dead-end, one-off technologies. The goal of once again launching American astronauts on an American rocket from American soil is fully enabled by this proposal.

The budget request plants the seeds for technologies that will be necessary in the future like landers, habitats, and in-space propulsion. It also proposes exciting new programs like the Mars Sample Return mission. Science funding in this budget is nearly $680 mil-

lion more than NASA planned for FY2020 under President Obama's last request. This additional funding maintains support for the Europa Clipper mission, the Mars 2020 Rover, and the James Webb Space Telescope. It also supports Earth science and heliophysics priorities from the National Academies of Science and the foundational research and analysis work that forms the backbone of our space science enterprise.

Aeronautics funding under the proposal is robust as well. It supports the demonstration of low-boom supersonic technologies that will hopefully inform regulatory relief of supersonic flight over land. It also addresses hypersonics that are critical to our national security, technologies that will enable the air traffic management and allow the safe adoption of uncrewed aviation systems.

Importantly, the budget request is also responsible. It attempts to reign in programs that bust their budget and defers the start of programs until they can demonstrate realistic cost, schedule, and performance metrics. The request funds the maintenance, operation, and facilities necessary to enable our space program. All too often these enabling functions are ignored, but we shortchange these obligations at our own peril. Thankfully, this request recognizes the role that safety, security, and mission services serves to facilitate space exploration, advance science, and protect lives and sensitive information.

Mr. Administrator, thank you for your appearance, today. I very much look forward to your testimony.

I yield back, Madam Chair.

[The prepared statement of Mr. Lucas follows:]

Ranking Member Lucas Opening Statement at Full Committee Hearing on NASA FY20 Budget Request

Apr 2, 2019
Opening Statement
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Mr. Administrator, thank you for your appearance, today. I look forward to your testimony.

Chairwoman JOHNSON. Thank you. Thank you, Mr. Lucas.
[The prepared statement of Ms. Horn follows:]

U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY

Opening Statement

Chair Kendra Horn (D-OK)

Full Committee Hearing:
A Review of the NASA Fiscal Year 2020 Budget Request
April 2, 2019

Good morning and thank you, Chairwoman Johnson, for holding this hearing to review NASA's Fiscal Year 2020 budget request, and welcome, Administrator Bridenstine.

I want to start by expressing my sincere appreciation for the talent and dedication of the NASA workforce, our international partners, and the academic and commercial communities that make our space program the envy of the world. All of you are integral to the plans we discuss this morning.

I think all of us in this room share a passion for the mission of NASA and the exciting projects that NASA and its partners are undertaking. That includes the human exploration theme and programs that are part of the Fiscal Year 2020 NASA budget. But, I have to pause here and ask, what budget and programmatic proposal are we actually considering here this morning? Because, Madame Chair, I'm concerned about the radical shifts, changes, and instability being sprung upon Congress as the Administration seeks to advance its ambitious Moon program.

Let's take a moment to review the last three to four months.

First, the Administration shut down the Federal Government for a total of 35 days, the longest shutdown in history, disrupting NASA programs, employees' lives, and contractors work. While the full extent of the shutdown impacts is not yet known, many projects will experience delays and some level of cost increase due to the disruption.

Second, in a delayed release of the FY 2020 budget request due to the shutdown, the Administration proposed a more ambitious Moon program-- to send humans to the lunar surface by 2028 --- while also proposing to cut a half billion dollars from the agency's topline relative to the FY 2019 enacted appropriation.

Third, just two weeks AFTER the Administration released its FY 2020 request for NASA, the Vice President announced that "it is the stated policy of this administration and the United States of America to return American astronauts to the Moon within the next five years." This is a full 4 years earlier than the ambitious date included in the FY 2020 Budget Proposal.

Fourth, last Friday, again just weeks AFTER releasing the FY 2020 Request, the Committee received notice of NASA's request for a major reorganization of NASA's technology and exploration activities that NASA is proposing through a "reprogramming request" to the Committee on Appropriations.

This request would create a new Moon to Mars Mission Directorate that would subsume the space technology program into a Directorate focused on large exploration development programs like the Gateway. NASA's request proposes other major organizational changes that, if approved, would bypass this Committee's authorizing role in considering such drastic reorganizational changes.

Finally, a full year and a half AFTER its Congressionally-directed due date, the Committee received the report directed in Section 435 of the NASA Transition Authorization Act of 2017. According to the report, it's clear that getting to the surface of Mars in the 2030s is impossible under this Administration's current approach to exploration. Moreover, the report acknowledges what many on this Committee have been surmising during past hearings—namely, that there is no actual Plan for a human Mars mission.

It states that NASA's Exploration Campaign Report, "is a high-level strategy…is mainly a plan for a plan…and may not ultimately play a substantive role in efforts to place humans in Mars orbit by 2033. Further specificity of NASA's long-term plans in a public document would help Congress and other public policy officials make informed decisions over the coming decades."

So, I return to my earlier question, exactly what proposal are we considering today?

We have a FY 2020 budget proposal that requests funds for a sustainable program to land humans to the surface of the Moon by 2028 and to establish a permanent presence there. We have a statement by the Vice President directing NASA to accelerate that date by 4 years, to 2024. And, as of just last Friday, we have a substantive analysis that raises numerous questions about NASA's Exploration Campaign and the extent to which the Moon program will get us to Mars.

These issues are not partisan. We have learned over several Congresses and Administrations that attempting to implement major programs through fits and starts creates confusion and often delays progress.

Changes in direction also present challenges for the Committee's work toward providing effective guidance and policy through the reauthorization process.

I hope the Administrator's testimony will provide some clarity, because the Space and Aeronautics Subcommittee will need to take a hard look at these issues as we work toward NASA reauthorization.

Thank you Madame Chair, and I yield back the balance of my time.

Chairwoman JOHNSON. At this time I will introduce our witness. James Frederick Bridenstine was sworn in as NASA's 13th Administrator on April 23, 2018. Prior to his nomination, he served as a Representative for Oklahoma's First Congressional District in the House of Representatives, and during his time in Congress, he served on the Armed Services Committee and right here on the Science, Space, and Technology Committee, as many of you well know. We are delighted to have the Administrator back before us today, and we look forward to his testimony on the Fiscal Year 2020 NASA budget request.

He has a history in the space and aeronautics field. He began his career in the U.S. Navy flying combat missions in Iraq and Afghanistan. After transitioning to the U.S. Navy Reserve, he returned to Oklahoma where he became the Executive Director of the Tulsa Air and Space Museum and Planetarium.

He has completed a triple major at Rice University, which is in Texas, and earned his MBA at Cornell.

As our witness should know, you will have 5 minutes for your spoken testimony, but your written testimony will be included in the record for the hearing. And when you have completed your spoken testimony, we will begin a round of questions. Each Member will have 5 minutes to question the panel. Mr. Bridenstine.

TESTIMONY OF JAMES F. BRIDENSTINE, ADMINISTRATOR, NASA

Mr. BRIDENSTINE. Thank you, Chairwoman Johnson and Ranking Member Lucas. It is an honor to be back in the Science Committee this time representing 17,000 of our country's finest employees at NASA. I understand, as the Chairwoman identified, that things are shifting. I will tell you that we submitted the budget request about 3 weeks ago now, and in that budget request there's a very new direction for our country.

The President has issued now Space Policy Directive-1. He says that we should go back to the moon. I like to say we should go forward to the moon because the way we're going to do it under Space Policy Directive 1 is unlike anything that's ever been done before. We're not going to the moon to leave flags and footprints and then not go back for another 50 years. This time we go, the President has said he wants to go sustainably. In other words, this time when we go, we're going to stay. But he says we're going to go to the moon, we're going to go with international partners, we're going to build a coalition of international partners to go sustainably to the moon, we're going to go with commercial partners. We're going to utilize the resources of the moon, in other words, the hundreds of millions of tons of water ice that have been discovered in the last 10 years, and then we're going to retire risk. We're going to prove technology, and we're going to take all of that for a mission to Mars. So that is what is on the agenda here.

I will tell you the first step in achieving that is continuing to advance the commercialization of low-Earth orbit, and we have now seen commercial resupply of the International Space Station prove to be very successful, and we are in the midst of watching commercial crew continue to show advancements, which has been very exciting. I think many of you in this room saw the Crew Dragon

docked to the International Space Station just a few short weeks ago.

Eventually, by the end of this year, we will be launching American astronauts on American rockets from American soil to the International Space Station for the first time since the retirement of the space shuttles in 2011, so that is a very exciting thing that we are looking forward to. But that's commercial crew. We've already completed commercial resupply capabilities and eventually want to get to commercialization of human habitats in low-Earth orbit.

All of this for the point of this: We think it's important—and I know this Committee has doubled down on this importance—NASA should be one customer of many customers in a robust commercial marketplace in low-Earth orbit. That includes launch, it includes habitation, and we want to have numerous suppliers that are competing on cost and innovation in low-Earth orbit. The reason for this is to drive down cost and increase access and then utilize the resources that have been given to us by this body to go to the moon sustainably with our international partners and our commercial partners to do things that only government can do. That's what NASA should be doing. And we look forward to advancing that agenda. In this particular budget, these agenda items are embedded in this budget.

I don't want to dismiss, though, how important the rest of what NASA does is. Right now, we have the Parker Solar Probe in orbit around the sun, in fact flying through the solar corona helping us better understand solar flares and corona mass ejections. We have of course dozens of satellites orbiting the Earth, sensing the Earth in every part of the electromagnetic spectrum, and those satellites are helping us better understand the climate and helping us in fact increase crop yields for a day when we can feed more of the world than ever before.

At the same time we're continuing planetary missions, and as a matter of fact in the last I guess 5 months now we landed InSight on Mars, which was an exciting day for the United States of America. In this budget you'll find that Mars 2020 is well-funded. You also find that there's funding for a Mars sample return. Mars 2020 is going to cache samples, and then after Mars 2020 we're actually going to bring samples back to Earth. It's important for this country to focus on finding life on another world.

I'm looking at my good friend Ed Perlmutter with his 2033 bumper sticker. It's a little distracting, Congressman, but I'll continue.

So planetary science is important. Of course astrophysics is important. We're focused like a laser right now on the James Webb Space Telescope, which is a big mission. It will make the United States the leader in astrophysics for the next 30 years. That's how important this mission is.

The budget is strong on aeronautics. We're on the brink of demonstrating the capability to fly across the United States at supersonic speeds without the sonic crack that can be so disruptive to infrastructure and people on the ground. So all of these missions are funded in this budget. We're proud of it.

It is absolutely true, Chairwoman, that the budget was focused on a 2028 moon landing. We have now gotten other direction from the President to go in 2024, and we are moving rapidly to get you the details that you need so that we can, in a bipartisan way—and I've committed to you, Chairwoman, and I'm committing to you now in a bipartisan way we want to be able to achieve that objective.

With that, I'll yield back.

[The prepared statement of Mr. Bridenstine follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
April 2, 2019

Statement of

James Bridenstine
Administrator
National Aeronautics and Space Administration

before the
Committee on Science, Space, and Technology
U.S. House of Representatives

Overview

Mr. Chairman and Members of the Committee, I am pleased to have this opportunity to discuss NASA's FY 2020 budget request of $21 billion. This budget represents a significant step in pursuit of the ambitious, long-term goals set for the Agency in legislation and in Space Policy Directive-1.

NASA is going forward to the Moon. We are building a sustainable, open architecture that returns humanity to our nearest neighbor as the next step in our long-term drive to send humans to the Moon and on to Mars. We are moving fast; we are incentivizing speed, and we are going to start taking "shots on goal" almost immediately. We look to land humans on the Moon within a decade. We are completing development of Orion, the spacecraft that will carry humans to lunar orbit, and the Space Launch System (SLS), the rocket that will launch Orion. We are pressing forward toward an uncrewed test flight of Orion around the Moon in 2020 and we are working to launch the Power Propulsion Element (PPE) in 2022, the first element of the Lunar Gateway, a spacecraft that will orbit the Moon and support future landings. Once habitation capability is added, the Gateway will serve as a reusable command module, supporting human missions to the surface of the Moon and giving us access to the entire lunar surface. Working with commercial partners and international partners, we seek to land humans on the surface of the Moon. We look forward to receiving industry proposals this July and moving forward on an ambitious schedule.

We are building for the long term, and this time are going to the Moon to stay. A sustainable exploration plan requires that we build within realistically available resources. We are designing an open, durable, reusable architecture that will support exploration for decades to come. Sustainability requires reusable systems and an openness to partnerships from across the commercial sector and around the world.

We are actively seeking partner contributions and participation. NASA is working to identify partnership opportunities that widen the pool of resources, enhance sustainability, and advance our most important exploration objectives.

Sustainability requires that we remain focused on the next goal beyond the Moon. Systems we develop for lunar exploration will be designed to contribute to a human exploration mission to Mars where feasible. Beyond developing, testing, and demonstrating the technology we need for the journey, we need

to understand the destination. Humans have, in fact, been exploring Mars for decades. We have moved from landers to small solar-powered rovers, and on to large nuclear-powered rovers. At the same time, we have invested in critical infrastructure in orbit around the planet. With the FY 2020 request, NASA will go beyond current capabilities to begin developing a Mars Sample Return mission, a high priority of the scientific community as well as an important precursor to human exploration.

This Exploration Campaign relies on seamless collaboration across the Agency, including human exploration and operations in low-Earth orbit (LEO) and beyond, technology development, and elements of science, as well as the rapidly advancing capabilities of our commercial partners. It draws upon decades of experience and data from our continuing efforts in LEO. NASA has played a pivotal role in enabling the ongoing and rapid expansion of commercial activity in LEO. Our commercial partners are set to make history – sending humans into space on commercially-developed, -owned, and -operated systems this year. This has been a long process, beginning with regular commercial cargo deliveries to the International Space Station (ISS); it will soon bring human spaceflight launches back to American soil. NASA is working to extend this success with commercial partners to the Moon and beyond.

The FY 2020 budget request supports our continuing efforts to improve the performance and safety of aircraft, crewed and uncrewed, here on Earth. NASA's Aeronautics research is returning to the X-plane business; our Low Boom Flight Demonstration Project (LBFD) is working toward a first flight of the X-59 QueSST supersonic flight demonstrator in FY 2021. We will push the sound barrier once again, this time with the goal of making practical commercial supersonic travel a reality, while again helping to foster economic activity.

Much of NASA's current infrastructure was built to support the Apollo Program. Sustainability also includes the ability of our infrastructure, capabilities, and facilities to effectively and efficiently support our missions, while including sufficient flexibility to meet future needs as we continue to explore. This budget includes significant new investments in NASA's mission support activities, to ensure that exploration in space is not limited by our capabilities on the ground.

NASA remains focused on exploring worlds that humans may never visit. NASA robotic missions have visited all the planets of the solar system, and the Parker Solar Probe is preparing to touch the Sun's atmosphere. While the long-lived Opportunity Rover has finally ceased functioning, the even longer-lived Voyager spacecraft has left the solar system. The search for life beyond Earth takes its next step with our planned mission to Europa. The unparalleled James Webb Space Telescope will open a new chapter in humanity's ongoing quest to explore and understand our universe.

NASA's focus on exploration also extends to the one planet known to support life. Exploring the Earth as a system from space, NASA is our leading source of information on the how the planet works, how the climate is changing, and what the future holds. No planet is more important to explore than our own. With a fleet of spacecraft operating in orbit NASA will continue its world-leading role exploring the home planet.

With the James Webb Space Telescope poised to look out into the cosmos and back to the time when the first stars were forming, humans landing on the Moon, and constellations of spacecraft exploring the solar system, NASA's FY 2020 request supports what is truly a golden age of exploration.

Human Exploration and Operations

The FY 2020 budget request supports bold new steps in NASA's Exploration Campaign. 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 FY 2020 resources NASA

needs to develop 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 supports NASA's plan to use a commercial rocket to deliver to cislunar orbit the Power and Propulsion Element (PPE) as the foundation of a Lunar Gateway no earlier than 2022.

The FY 2020 request includes $5,021.7 million for Deep Space Exploration Systems, and $4,285.7 million for Low-Earth Orbit and Spaceflight Operations, including the ISS and Space Transportation – both commercial crew system development and ongoing crew and cargo transportation services that resupply the ISS.

NASA will continue its mission in LEO with the ISS to enable exploration, while continuing to perform research that benefits humanity, supporting National Laboratory research by private industry and other organizations, and working towards reducing operations and maintenance costs. NASA will create new opportunities for collaboration with industry on the ISS and develop public-private partnerships for exploration systems that will extend human presence into the solar system. NASA is working to transition our work in LEO, including our international partnerships, to be based on commercially-provided space station services that help enable deep space exploration and private sector expansion in LEO. To support this transition, the ISS will focus near-term activities on supporting commercial industry as well as meeting government requirements in LEO. In parallel, NASA is creating a focused effort aimed at long-term American operations in LEO independent of the ISS.

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 the joint efforts of NASA and CASIS, the ISS National Lab has reached full capacity for allocated crew time and upmass and downmass.

Space life and physical science research will continue to follow the guidance of the National Academies' decadal studies. NASA-sponsored researchers will be a major user of the ISS and an early user of new commercial platforms as they: enable exploration with research in fluid physics, combustion, microbiology, food production, and animal models; and produce knowledge for use on Earth in materials science, complex fluids, and fundamental cold atom physics. Space life and physical science research expertise will be shared with new Governmental, commercial, and academic researchers to accelerate their productive use of LEO for research and technology development and increase demand for LEO capability.

NASA's Human Research Program (HRP) will continue to conduct cutting-edge research on the effects of spaceflight on the human body, including experiments that require the microgravity environment of the ISS. HRP will support the development of deep space exploration habitat concepts to ensure crew health and performance risks are adequately addressed.

Maintaining the ISS requires service providers to sustain a regular 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 Northrop Grumman, have provided cargo deliveries to the ISS. Using the launch vehicles developed in partnership with NASA, SpaceX has helped to bring some of the commercial satellite launch market back to the United States and has contributed to a reduction of launch costs. Northrop Grumman has begun to explore commercial markets by offering LEO missions for up to a year after their ISS cargo mission is completed. Under new CRS-2 contracts, SpaceX, Northrop Grumman, and Sierra Nevada Corporation will deliver critical science, research, and technology demonstrations to the ISS over five years from 2020 through 2024. The addition of Sierra Nevada will

add the unique capability to return cargo to various runways, enabling quicker return of cargo for ISS users.

NASA and its commercial partners, Boeing and SpaceX, will soon make history as they prepare to launch humans to the ISS. Before the companies can begin regularly flying long-duration missions to the orbiting laboratory, they first need to demonstrate their systems' capabilities through a series of flight tests. SpaceX's uncrewed Demo-1 launched on March 2, 2019, successfully docked to the ISS, re-enterd Earth's atmosphere, and was recovered after splashing down in the Atlantic Ocean. Boeing is planning for an uncrewed launch in April. Through NASA's Commercial Crew Program, American astronauts will soon launch to orbit from American soil for the first time since the Space Shuttle retired in 2011. Further, for the first time in history, humans will travel to space on systems owned, built, tested, and operated by private companies. The recent flight of the Crew Dragon and upcoming flight of the CST-100 Starliner will demonstrate the enormous potential of commercial partnerships for the human exploration and development of space.

Through the Commercial LEO Development program, NASA will continue to leverage its resources and capabilities to enable the development of a commercial market in LEO. The program's first solicitation activity, which will go out in the next few months, will support the development of new commercial LEO platforms and capabilities. These partnerships will further accelerate the transisition of human spaceflight operations in low-Earth orbit to commercial partners for NASA and non-NASA needs.

NASA is building a deep space launch and crew system – the Orion spacecraft, the heavy-lift SLS launch vehicle, and the supporting Exploration Ground Systems (EGS) – to support the Exploration Campaign. The SLS Block 1 cargo variant will be capable of delivering Orion to cislunar space in the early 2020s, While more powerful SLS configurations remain an important future capability, recent delays in SLS core stage manufacturing require that NASA concentrate in the near term on the successful completion of EM-1 and EM-2 rather than split attention between EM-1, EM-2, and developing an upgraded upper stage. As a result, SLS Block 1B final development efforts will be deferred. The Orion crew vehicle will carry up to four humans to the lunar vicinity for up to 21 days, and when combined with additional habitation can support longer-duration missions. The Orion will also be able to provide key initial life-support and abort capabilities to Gateway.

The budget request supports a planned SLS/Orion mission, Exploration Mission-1 (EM-1) that would send an uncrewed Orion spacecraft around the Moon. This would be followed by the first crewed SLS/Orion mission, Exploration Mission-2 (EM-2) and an annual launch cadence thereafter. The EM-1 and EM-2 launch dates are under review pending completion of independent assessments of core stage production and the integrated mission schedule. NASA is also assessing alternative architectures for EM-1 that could include the use of commercial launch vehicles. Our goal is to maintain our planned EM-1 schedule. NASA will keep the committee apprised of our findings as we analyze these options. NASA remains focused on the major risk areas associated with first-time production and testing of the SLS core stage, integrated assembly and test of the Orion crew and service module, and integrated operations at the Kennedy Space Center. The FY 2020 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. SLS, Orion, and EGS are critical capabilities for maintaining and extending U.S. human spaceflight leadership beyond LEO to the Moon, Mars, and beyond.

As a key part of the Exploration Campaign, NASA will establish the Lunar Gateway, a small way station that will orbit the Moon and enable human and robotic missions to the lunar surface. The Lunar Gateway will support exploration on and around the Moon, and sustainable human lunar surface exploration missions by supporting reusable human lunar landers. It will be a temporary home for astronauts and will foster growing domestic and international economic opportunities for commercial logistics and refueling

services, as well as providing robust communications with spacecraft in cislunar space and on the lunar surface.

The PPE is the first element of the Lunar Gateway which will be launched on a commercial rocket in 2022 and placed in orbit around the Moon. The PPE will demonstrate advanced high-power solar-electric propulsion (SEP) bus systems that will support both future NASA and commercial applications. The PPE will supply power and propulsion for elements and systems on the Lunar Gateway as well as communication to and from Earth, other spacecraft, and missions to the lunar surface. The Lunar Gateway is intended to be capable of supporting human-class lander deployments and operations. Once the PPE and mimimal habitation capabilities have been delivered to cislunar space, a crew of four - launched on Orion - will be able to visit the Lunar Gateway on their way to the lunar surface.

The Lunar Gateway will be launched on competitively procured commercial launch vehicles and assembled in orbit around the Moon where it will be used immediately as a staging point for missions to the lunar surface. It can evolve depending on mission needs, and will support human-class reusable landers, landing a crew of up to four astronauts on the lunar surface and ultimately developing sustaining lunar operations on the Moon. This budget integrates the NASA Docking System (NDS) into the modules of the Lunar Gateway, reducing development cost and allowing NASA, international and commercial partners to easily dock with Lunar Gateway to support lunar landers (including reusable human), the Lunar Gateway itself and science objectives. Further, the early development of commercial docking and delivery capabilities will be essential for developing a sustainable and scalable lunar program. Delivery of Lunar Gateway and lunar lander elements, including refueling of these elements, will create a reusable hub for sustainable lunar activity and feed forward to Mars. The Gateway and lunar surface campaign will benefit from components being provided by International partners. The Gateway will be functional for lunar surface support with the addition of a utilization module planned as the next element after the PPE element.

NASA is supporting the development of commercial lunar exploration capabilities leading to a human lunar landing. NASA is focused on engaging U.S. industry partners using innovative approaches to combine lunar robotics, a cislunar presence, and lunar landing capabilities building up to a human-rated lander. NASA's lunar efforts will incorporate results from the following.

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

- Through Commercial Lunar Payload Services (CLPS), NASA selected nine U.S. companies to bid on delivery services to the lunar surface. Lunar payloads from a variety of customers, including NASA, will fly on contracted missions starting in 2020, enabling critical technology demonstrations and scientific observations.

- The budget request supports commercial development of a large lunar lander that can initially carry cargo and later astronauts to the surface of the Moon. NASA issued a solicitation on February 7, 2019 to seek proposals from industry for human lander system studies, risk reduction, development, and spaceflight demonstrations. These Next Space Technologies for Exploration Partnerships (NextSTEP) will enable rapid development and flight demonstrations of human lunar landers by supporting critical studies and risk reduction activities, maturing requirements, tailoring applicable standards, and creating technology maturation plans.

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

Missions to the Moon and cislunar space will also serve as a stepping-stone, a training ground, and a platform to strengthen commercial and international partnerships and prepare for future human missions to Mars and other destinations.

The FY 2020 budget request provides for critical infrastructure indispensable to the Nation's access to and use of space, including those provided under the Space Communications and Navigation (SCaN) Program, the Communication Services Program, the Launch Services Program, Rocket Propulsion Testing, and Human Space Flight Operations.

Human missions to the Moon and Mars will require advanced space communications and navigation capabilities. SCaN's technology development effort invests in leading-edge communications technologies to enable, improve, and mature spacecraft communication and navigation technologies. NASA is conducting studies to identify future technologies under development that can be infused to support NASA exploration missions in the 2022-and-beyond timeframe. These studies include Requests for Information and funded Broad Area Announcements to leverage the creativity of industry partners through mechanisms such as public-private partnerships that will be central to NASA's future communications architecture. NASA is also initiating a Communications Services Program, based on our successful Launch Services Program, which will begin work towards matching future NASA missions with communications services furnished by commercial providers.

Exploration Technology

NASA's FY 2020 request includes $1,014.3 million for Exploration Technology to accelerate technology development to enable human and robotic exploration of the Moon and Mars and foster commercial expansion in LEO and beyond. Technology drives exploration with investments spanning the Technology Readiness Level (TRL) spectrum, advancing early-stage concepts and maturing key technologies and systems that enable demonstrations in relevant environments.

Within Exploration Technology, NASA will accelerate development of lunar surface technologies through the Lunar Surface Innovation Initiative, driving new essential technologies required for humans to successfully operate on the lunar surface. Utilizing the five-year horizon, NASA will transition key technologies through the ground demonstration phase toward flight demonstrations. The Lunar Surface Innovation Initiative will include the technology areas highlighted below.

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

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

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

Additionally, computer systems for spaceflight are exposed to a hostile radiation environment that can impact performance and reliability. NASA will address this challenge in FY 2020 by testing a powerful, radiation-hardened computer processor that will enable advanced precision landing, hazard avoidance, and autonomous operations.

NASA plans to launch two Exploration Technology demonstration missions in 2019: 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. The Green Propellant Infusion Mission demonstrates a propulsion system that could reduce spacecraft processing costs by replacing hydrazine propellant with a propellant that is less toxic and has approximately 40 percent higher performance by volume. The Deep Space Atomic Clock will demonstrate the potential of a 50-fold increase in clock accuracy for improved deep space navigation and improved gravity science measurements.

NASA is working to an August 2020 launch readiness date for its Laser Communications Relay Demonstration project. The project will demonstrate optical communications technology in an operational setting, providing data rates up to 100 times faster than today's radio-frequency-based communication systems.

In 2020, the Solar Electric Propulsion project will complete the Critical Design Review for the electric propulsion subsystem, and build qualification units to conduct qualification testing of the Solar Electric Propulsion engineering development units for the high-power electric propulsion string. The first demonstration of this system will be the 50-kilowatt-class PPE for NASA's Lunar Gateway spacecraft.

Other technology development that Exploration Technology supports includes critical technology for the Mars 2020 mission to be delivered this year; inflatable aerodynamic decelerator technology which could enable high mass Entry, Descent, and Landing on Mars; and In-Space Robotic Manufacturing and Assembly, with the potential to revolutionize exploration. These and many more technology efforts are enabling NASA's most challenging missions.

Science

NASA's Science Mission Directorate leverages space-, air-, and ground-based assets to answer fundamental questions about the Earth, the solar system and the universe, and our place in the cosmos. Our scientists, engineers, and technologists work with a global community of researchers to provide the scientific discoveries that advance critical understanding and inform decision-making. Whether through disaster response, natural resource management, planetary defense, or space weather monitoring, NASA provides tangible benefits that help protect and improve life on Earth. At the same time, NASA is leading the quest to answer some of most pressing human questions, among them how Earth and the universe evolved, how life emerged, and whether we are alone in the universe.

The FY 2020 budget requests $6,303.7 million for NASA Science, including $2,622.1 million for Planetary Science, $844.8 million for Astrophysics, $352.5 million for JWST $704.5 million for Heliophysics, and $1,779.8 million for Earth Science. The budget enables NASA to continue advancing national science and exploration goals while maintaining its global leadership position through a balanced and integrated science program. This year's budget request reflects a concerted effort to seek and execute new partnerships that will allow the Agency to leverage the innovation, resources, and know-how of the

full breadth of the global science enterprise, including other U.S. and foreign agencies, as well as commercial, academic, and other non-Governmental partners.

Science remains critical to the exploration goals of the Agency, contributing both capabilities and knowledge needed to advance human and robotic exploration of the Moon, Mars, and beyond. The Lunar Discovery and Exploration program advances an integrated strategy for exploration, not only through improved collaboration across the Agency but also by leveraging interagency, international, and commercial partnerships. In November 2018, NASA selected nine U.S. companies to bid on delivery services to the lunar surface through Commercial Lunar Payload Services (CLPS) contracts. Lunar payloads from a variety of customers, including NASA, will fly on contracted missions starting in 2020, enabling critical technology demonstrations and scientific observations; most recently, NASA selected 10 proposals for the Development and Advancement of Lunar Instrumentation (DALI) program, which will support instruments that will fly on future lunar missions. NASA's Lunar Reconnaissance Orbiter (LRO), which marks its tenth anniversary in 2019, continues to help scientists characterize the lunar surface, providing insights into lunar resource analysis that could support future human exploration.

NASA's Planetary Science Division develops and operates increasingly sophisticated missions to reveal new knowledge of our Solar System's content, origin, evolution, and the potential for life elsewhere. With spacecraft in place from the innermost planet to the very edge of the Sun's influence, this year's budget request reinvigorates robotic exploration of our Solar System, supporting the long-term scientific study of the Moon, Mars, and beyond.

NASA's robust Mars Exploration Program continues to achieve great things. In November 2018, the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) lander reached the Martian surface, marking the Agency's eighth successful soft landing on the Red Planet. A robot geologist, InSight will yield new discoveries about the Martian interior, providing an unprecedented look at its core structure and heat flow. Cruising behind InSight were two experimental, briefcase-sized spacecraft named Mars Cube One (MarCO) – the first ever planetary CubeSats – which successfully relayed data back to Earth from the InSight lander during its descent to the Martian surface.

The budget request also supports continued progress of the Mars 2020 rover, which – after an intensive effort to identify the most promising landing site – will head to the Jezero Crater following a July 2020 launch. A precursor to human missions to Mars, Mars 2020 will continue to search for evidence of life on the Red Planet and collect a cache of core samples.

In 2020, NASA will commence studies and development of a Mars Sample Return mission – the highest priority strategic mission identified by the scientific community in the most recent planetary science decadal survey and endorsed in the 2018 midterm assessment – that would allow for the return of the Mars 2020 rover samples. Leveraging commercial and international partnerships, such as with the European Space Agency, this mission may launch as early as 2026.

Beyond Mars, NASA will continue development of the next Discovery missions, Lucy and Psyche, as well as the cutting-edge Europa Clipper strategic mission to fly by Jupiter's moon – a first step in exploring ocean worlds and their potential habitability. And just this year, NASA celebrated the first flyby of a Kuiper Belt object (MU69/Ultima Thule) with our New Horizons mission. The data collected from over four billion miles away from Earth will help answer basic questions about the surface properties, geology, and atmospheres of these primitive bodies.

In December 2018, NASA's first asteroid sampling mission, the Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx), entered orbit around Bennu, the smallest object a spacecraft has ever orbited. In 2020, OSIRIS-REx will have completed its mapping of

Bennu, informing selection of the most promising sample collection site. Its measurements of this potentially hazardous object (Bennu's orbit could bring it relatively close to Earth at the end of the next century), will not only shed light on the early history of our Solar System, but will also inform the design of future missions to mitigate possible asteroid impacts on Earth.

Built as a cohesive, international program for Near-Earth Object (NEO) detection and mitigation technology development, NASA's Planetary Defense Program will continue to fund the NEO Observations project and development of a space-based infrared instrument for detecting NEOs with this year's budget request. Meanwhile, the Double Asteroid Redirection Test (DART) to demonstrate the kinetic impact technique for asteroid deflection will continue to make progress towards its planned 2021 launch.

NASA's Astrophysics Division seeks to understand the universe and our place in it, probing how it works and peering into the origin and evolution of galaxies and stars. Through a coordinated program of research, space-based missions, and technology development, it also explores the formation of planetary systems and seeks to understand how habitable environments develop, a key aspect of the search for life in the universe.

In 2018, NASA bid farewell to the Kepler mission, after nine years of searching for planets outside our Solar System. Kepler discovered almost 2,700 new exoplanets, bringing the total from all sources to over 3,900 known exoplanets. Kepler's legacy serves as the foundation for NASA's next planet-hunting mission, the Transiting Exoplanet Survey Satellite (TESS), launched in April 2018. TESS has already found 12 new exoplanets, including four new multi-planet systems. During its two-year primary mission, TESS will observe nearly the whole sky, providing a rich catalog of worlds around nearby stars, including valuable targets for the James Webb Space Telescope to explore. The 2020 budget accommodates the funds needed to support the revised March 2021 launch date of the James Webb Space Telescope, the largest and most powerful space telescope to be developed to date. Webb will join NASA's family of observatories to examine 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.

The budget request also supports operations for the airborne Stratospheric Observatory for Infrared Astronomy (SOFIA), a partnership with the German Aerospace Center; SOFIA will complete its five-year prime mission in 2019. Flying into the stratosphere above 99 percent of Earth's infrared-blocking atmosphere, SOFIA allows astronomers to study the solar system and beyond in ways that are not possible with ground-based telescopes, from almost anywhere in the world.

In order to maintain a balanced science program that optimizes overall scientific return, the FY 2020 budget request again proposes termination of the Wide Field Infrared Survey Telescope (WFIRST), given its significant cost and higher priorities within NASA, including completing the delayed James Webb Space Telescope.

The budget also enables NASA to fully support competed Astrophysics missions and research, and follow the decadal- survey-recommended cadence of new Astrophysics Explorers missions. By the end of FY 2019, NASA plans to release Announcements of Opportunity for the next Astrophysics Small Explorer and Mission of Opportunity missions for an initial selection in 2020.

NASA's Heliophysics Division studies the nature of the Sun, how it affects Earth and other objects in the solar system, and the very nature of space itself. Understanding the Sun and its interactions with the space environment, including near-Earth space, helps scientists identify the causes and impacts of space

weather phenomena, which can threaten spacecraft and astronauts, and affect human technological infrastructure and activities, both on and around Earth, and beyond.

The Heliophysics Division adopts a holistic approach to the study of the Sun and its connection to Earth and other planets – venturing to the very edge of the Sun's influence and beyond. In December 2018, Voyager 2 exited the heliosphere, the protective bubble of particles and magnetic fields created by the Sun, a milestone only achieved once before – by Voyager 1 in 2012. In over 40 years in space, Voyager 2 has traveled a staggering 18.5 billion miles and is NASA's longest-running mission.

In 2018, several successful launches also expanded the Heliophysics System Observatory, including the January 2018 launch of the Global-scale Observations of the Limb and Disk (GOLD) instrument, and the August 2018 launch of the Parker Solar Probe, which completed its first of 24 planned orbits around the Sun in January 2019. Together with GOLD, the Ionospheric Connection Explorer (ICON) instrument launching in 2019 will provide the most comprehensive observations of the ionosphere – a region of charged particles in Earth's upper atmosphere. In July 2018, NASA selected the Interstellar Mapping and Acceleration Probe (IMAP), identified as a priority in the most recent solar and space physics decadal survey, to launch in 2024 to study the boundary of the outer solar system where the solar wind ends. Also, in 2020, NASA will launch Solar Orbiter, a joint collaboration led by the European Space Agency, into orbit around the Sun in order to better understand the dynamics of the heliosphere.

NASA continues to work with its agency partners to reduce gaps between space weather research and operations. The budget initiates the Heliophysics Space Weather Science and Applications project to further strengthen the feedback between fundamental research and operational forecasting needs by improving the transition of science results into operational products. The budget also provides for a potential new Small Explorer-class space weather mission. This will lay the groundwork for a future Space Weather Mission line to focus on resolving fundamental science problems required to improve space weather prediction, and serve as a pathfinder for observation technology for the National Oceanic and Atmospheric Administration's (NOAA's) operational space weather missions.

NASA's Earth Science Division develops and operates space-based and airborne missions that obtain revolutionary observations of our planet. NASA Earth Science works with the scientific community to coordinate and integrate measurements to improve quantitative understanding of our planet and accurately model Earth's complex system of interacting processes. The program also teams with government and commercial partners in the U.S. and internationally to use the measurements and understanding to develop and demonstrate applications that will provide direct benefit to our Nation, and indeed all of humanity.

In 2018, NASA launched two strategic missions recommended by the 2007 Earth Science decadal survey: Gravity Recovery and Climate Experiment Follow-On (GRACE-FO); and Ice, Cloud and land Elevation Satellite-2 (ICESat-2). The twin satellites of GRACE-FO are continuing the original GRACE mission's 15-year legacy (2002-2017) of measuring the changing mass of ice sheets and glaciers and tracking Earth's water movement across the planet. ICESat-2, the follow-on to NASA's ICESat mission (2003-2009), is providing unprecedented data on the topography of ice, forests, and oceans. In November 2018, the Operation IceBridge 2018 Antarctic Field Campaign concluded successfully after flying under ICESat-2 orbits to validate and verify the new satellite's measurements.

In addition, NASA Earth Science is collaborating with the Human Exploration and Operations Mission Directorate to utilize the ISS for Earth observations. NASA Earth Science launched two low-cost, competitively selected missions to the ISS in 2018. The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) instrument is measuring agricultural water use, vegetation stress, and drought warning conditions. In December 2018, the similarly low-cost, competitively selected

Global Ecosystem Dynamics Investigation (GEDI) vegetation canopy lidar instrument was launched to the ISS and is now embarked on its science mission to make 3D maps of the world's forests.

Launching to the ISS in spring 2019, the Orbiting Carbon Observatory-3 (OCO-3) instrument will continue measurements of the complex dynamics of Earth's carbon cycle, increasing understanding of the regional sources and sinks of carbon dioxide. The FY 2020 budget request also funds continued progress of Landsat 9 for a launch as early as FY 2021. As part of the Sustained Land Imaging program architecture, Landsat 9 will enable continuity of the critical, long-term land imaging data record begun in 1972 with NASA's joint agency partner, the U.S. Geological Survey. Consistent with the FY 2019 budget request, the FY 2020 request proposes termination of the Plankton Aerosol Cloud ocean Ecosystem (PACE), and Climate Absolute Radiance and Refractivity Observatory Pathfinder (CLARREO-PF) missions.

NASA Earth Science continues to explore innovative partnerships and new approaches, including the acquisition of commercial data products from small satellite constellations. In September 2018, the Earth Science Division awarded contracts to three commercial data products providers. Through this pilot program, NASA-funded researchers will examine the scientific value of the data to help determine the utility of the private sector's constellation-based products for advancing NASA's science and applications development goals. The 2020 budget request continues support for the integration of NASA Earth Science efforts with non-Governmental partners through these and other activities, such as commercial hosting and new partnerships (such as the NASA-Conservation International collaboration announced in February 2018).

NASA Science leads the Nation on a journey of discovery through its nearly 100 missions. In every step, we share the adventure with the public and partner with others to substantially improve science, technology, engineering, and mathematics (STEM) literacy and understanding nationwide. In 2019, the National Academies will conduct an assessment of our Science Activation program, which since its establishment in 2016 has competitively selected over 25 awardees, enabling more than 200 partnerships that connect NASA science experts and content to learners of all ages in communities across the land.

Aeronautics

Aviation moves the world, and an efficient and safe air transportation system is fundamental to the future of the U.S. economy. NASA's cutting-edge aeronautics research is delivering new concepts and technologies which will change the face of aviation as we know it, boosting U.S. technological and economic leadership in this global industry and creating high quality American jobs. The FY 2020 budget requests $667 million for NASA aeronautics research.

NASA is enabling quiet commercial supersonic flight through construction of the X-59 supersonic flight demonstrator, with a first flight planned for FY 2021. NASA will then conduct a first-of-its kind, multi-year flight research campaign over populated areas to gather data about community response to quiet supersonic flights, enabling domestic and international regulators to establish a new supersonic noise standard. This capability will position the U.S. aviation industry to supply global customers with future supersonic aircraft products.

NASA is collaborating with industry to investigate innovative technology for subsonic aircraft, including advanced wing design, transformative structures, propulsion-airframe integration, and small-core turbine engines. NASA also is leading research into new components, technologies, and powertrain architectures for electric or hybrid electric systems that can bring about revolutionary improvements in small and large transport aircraft. NASA's work on the X-57 Maxwell aircraft – an all-electric, general-aviation-size plane – is already delivering important lessons to the community about designing, building, and operating

an all-electric system. Ground tests this year and flight tests next year will provide valuable insights into the challenges and opportunities of electric aircraft.

Building on these activities, NASA has begun a multi-year effort to solve the technical challenges associated with a 1-Megawatt (MW) power electric aircraft propulsion system – enough energy to power 165 homes. NASA will refine concepts and technologies and validate new electric systems through ground and flight tests. Realizing a practical 1-MW electric aircraft propulsion system has never been accomplished and is an area of notable international competition. To support this work, NASA has commissioned the world-leading NASA Electric Aircraft Test Facility (NEAT) capable of conducting full-scale ground tests of high-power electric propulsion systems.

In addition to developing new vehicle technologies, NASA is conducting research to make design and manufacturing processes more efficient and reduce the time and cost to build aircraft. Next year, NASA will complete the Advanced Composites Project, a six-year focused effort in partnership with industry to significantly reduce the time needed to develop and certify new composite structures for aerospace applications.

In 2020, NASA will complete demonstrations of technologies to integrate operations of larger Unmanned Aircraft Systems (UAS) into the existing National Air Space (NAS) as well as manage smaller vehicles safely at lower altitudes. Those efforts are providing the foundation for another major transformation of the aviation sector being led by NASA – creation of an urban air mobility (UAM) system that is safe, economical, and environmentally friendly to move people and packages in population centers.

NASA will begin a new Advanced Air Mobility project in FY 2020 to enable the emergence of UAM. NASA is preparing a series of "Grand Challenges" that will provide a means to assess the maturity of key systems for UAM. Through these Grand Challenges, NASA will serve as a catalyst for companies to rapidly develop and demonstrate their capabilities, while setting the course for needed research and investment. Initial community response to NASA's leadership in UAM has been strongly supportive.

NASA research is enabling a transformed airspace system that supports efficient operations of all vehicles across these different market segments, and gives citizens the confidence that every flight is safe and secure. NASA will complete a series of Airspace Technology Demonstrations (ATDs) with the Federal Aviation Administration (FAA), airlines, and airport operators to demonstrate new capabilities for managing efficient airline operations. A final high-fidelity demonstration of all integrated system capabilities will support delivery of the research and development results the FAA needs to advance NextGen capabilities and improvements to meet the FAA's air traffic management needs. NASA then will turn its attention to new research to address the safety and efficiency challenges of a more complex airspace supporting a broad range of new users.

NASA continues its investment in unique specialized facilities and experts who conduct fundamental research to address key challenges in hypersonic flight. NASA coordinates closely with partners in the Department of Defense (DOD) to leverage DOD investment in ground and flight activities to develop and validate advanced physics-based computational models as building blocks towards a long-term vision for hypersonic flight. At the same time, the DOD benefits from NASA hypersonics expertise, analyses, testing capabilities and computational models.

NASA aeronautics research is conducted in partnership with the aviation community to transform aviation as we know it, and find solutions to aviation system needs that will provide benefits in mobility, environmental sustainability, and safety, while ensuring continued long-term U.S. aviation technology leadership in this rapidly expanding global industry. NASA investments are enabling the early stages of the future airspace system that will enable all users – from UAS to UAM to traditional airlines – to

seamlessly access the airspace and safely and efficiently, with great benefit to U.S. industry and passengers alike.

STEM Engagement

NASA's FY 2020 budget proposes the termination of NASA's Office of STEM Engagement and its portfolio of domestic assistance awards (grants and cooperative agreements), and instead prioritizes funding toward an innovative and inspirational program of exploration. While the FY 2020 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) 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, focused functional office 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

In this budget, NASA will simultaneously implement multiple large development programs in order to return to the surface of the Moon by 2028. To be successful, NASA must have the institutional capabilities and facilities necessary to efficiently and effectively support these programs, which is why this budget proposes important new investment in Mission Support. NASA's mission support programs directly enable the Agency's portfolio of missions. The FY 2020 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. Over the past 60 years, NASA has leveraged unique test facilities to develop new and innovative vehicles and technology for space exploration. Now, commercial companies are also leveraging this unique infrastructure. Over 80 percent of NASA facilities are beyond their constructed design life, and NASA faces the challenge of a deferred maintenance backlog of ~$2.3B. The 2020 budget includes additional funding critical to renewing our infrastructure while we continue to divest of unneeded, costly facilities.

In the area of information technology (IT) services, NASA continues to improve management and strengthen NASA's cybersecurity capabilities in order to safeguard critical systems and data. We have made significant progress over the past several years, raising NASA's score on the Federal IT Acquisition Reform Act (FITARA) from an "F" in 2015 to a B+ this past year. The 2020 budget provides critical resources to continue strengthening cyber security protections and funding to help modernize NASA's IT systems in support of future mission objectives. In FY20, the Agency will continue its efforts to implement and develop optimal solutions. Examples include IT consolidation, automated segmentation architecture and end user cloud migration. NASA continues to transition its IT to an enterprise governance and operating model.

Conclusion

NASA's FY 2020 budget request provides for the foundation of a national exploration campaign that will create an architecture that is open, sustainable and agile. The Space Launch System and Orion, critical components of our exploration architecture, will reach important milestones in construction and testing this year as the program works through significant development challenges, and our new lunar command module, the Gateway, will see international and commercial partnerships solidified and construction begin. We have called on American companies to help design and develop human lunar landers and reusable systems for surface activities. In LEO, our Commercial Crew program remains strong and will soon be delivering American astronauts, on American rockets, from American soil to the ISS for the first time since 2011.

With the FY 2020 request NASA will initiate the first round-trip mission to the Red Planet with a Mars sample return mission, and many of the technological advancements we achieve moving forward to the Moon will provide critical data and capabilities for future robotic and crewed Mars missions. We will continue to pursue transformative aeronautics technology as we develop the next generation of aircraft and make air travel safer and more efficient. We will increase our understanding of our home planet and move out on ambitious programs to study the far reaches of our solar system and beyond.

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

James Frederick "Jim" Bridenstine was nominated by President Donald Trump, confirmed by the U.S. Senate, and sworn in as NASA's 13th administrator on April 23, 2018.

Bridenstine was elected in 2012 to represent Oklahoma's First Congressional District in the U.S. House of Representatives, where he served on the Armed Services Committee and the Science, Space and Technology Committee.

Bridenstine's career in federal service began in the U.S. Navy, flying the E-2C Hawkeye off the USS Abraham Lincoln aircraft carrier. It was there that he flew combat missions in Iraq and Afghanistan and accrued most of his 1,900 flight hours and 333 carrier-arrested landings. He later moved to the F-18 Hornet and flew at the Naval Strike and Air Warfare Center, the parent command to TOPGUN.

After transitioning from active duty to the U.S. Navy Reserve, Bridenstine returned to Tulsa, Oklahoma, to be the Executive Director of the Tulsa Air and Space Museum & Planetarium.

Bridenstine was promoted to the rank of Lieutenant Commander in 2012 while flying missions in Central and South America in support of America's war on drugs. Most recently, he transitioned to the 137th Special Operations Wing of the Oklahoma Air National Guard.

Bridenstine completed a triple major at Rice University, and earned his MBA at Cornell University. He has three children with his wife, Michelle.

Chairwoman JOHNSON. Thank you very much.

At this point we will begin our first round of questions, and I yield 5 minutes to myself.

We appreciate all that you have brought to NASA and appreciate you being here this morning.

Two weeks ago, 2 weeks after the Administrator released the Fiscal Year 2020 budget request, Vice President Pence announced that the United States would send Americans to land on the moon in 2024, 4 years earlier than the 2028 goal included in Fiscal Year 2020 request. What is the justification for this crash program? What will it cost, and how achievable is this accelerated schedule?

Mr. BRIDENSTINE. I think it's important for the Nation to continue advancing our progress and for us, as leaders of this country, to demonstrate a continued advancement. And I think that's ultimately the objective here.

I know I just saw Ed Perlmutter put up, Chairwoman, the 2033 bumper sticker. We want to achieve a Mars landing in 2033. In order to do that, we have to accelerate other parts of the program. The moon is a big piece of that. By moving up the moon landing 4 years we can in fact—and I know you've probably seen the STPI (Science and Technology Policy Institute) report at this point, which was called for by this Committee—we can move up the Mars landing by moving up the moon landing. The moon is the proving ground.

Like I said, if—we have to be able to utilize the resources of another world, and on the moon we now know that there's hundreds of millions of tons of water ice. Water ice represents air to breathe, it represents water to drink, it represents fuel, liquid oxygen. Liquid hydrogen is the same fuel that powered the space shuttles. It's the same fuel that will power the SLS rocket. So we need to utilize those resources.

Remember, when we go to Mars, when we go to Mars we're going to be there for at least 2 years. Why? Because Earth and Mars are on the same side of the sun once every 26 months, so we need to learn how to live and work in another world. The moon is the best place to prove those capabilities and technologies. The sooner we can achieve that objective, the sooner we can move on to Mars. And that's ultimately our objective here.

Chairwoman JOHNSON. When were you first told that the Vice President was going to direct NASA to land astronauts on the moon in 5 years? And were you informed before the Fiscal Year 2020 budget release or did he ask for you to provide him information on the analysis regarding the crash programs and the costs and the feasibility prior to his speech?

Mr. BRIDENSTINE. So the Vice President and I had had conversations about accelerating the path to the moon, and we had had conversations about what that might look like, what is feasible, how is it possible, and then ahead of his announcement, yes, he had told me that he was intending to make that announcement, and he was—wanted to make sure that that was within the realm of possibility. And of course I told him that I believed it was. Of course I talked to folks at NASA. And at the end of the day, that's the new direction that we have, and I believe that this is a great oppor-

tunity for this agency. I think it's a great opportunity for the country. And I think we can move out on it and achieve it.

Chairwoman JOHNSON. Thank you. Now, how much funding will be needed in each of the next 5 years to meet the Vice President's 2024 directive?

Mr. BRIDENSTINE. So that goes to an amendment to our budget request, which we are working on right now to achieve. The elements of getting to the moon in 2028 are all present, so we know we need to accelerate SLS and the Orion crew vehicle with the European Service Module. We need to accelerate the Gateway, the power and propulsion element, the habitation module in orbit around the moon, and then we need to accelerate a landing capability, which would include a transfer vehicle from the Gateway to low-lunar orbit, a descent module, and an ascent module.

All of those elements are on the agenda for 2028. In order to achieve 2024, we need to take some of those elements and move them forward to achieve that objective. And what we're working on right now at NASA, is compiling the data necessary to come back to this Committee, to come back to Congress and ask for an amendment to our budget request and attempt to win the buy-in of this critically important Committee and the United States Congress.

Chairwoman JOHNSON. Thank you. And do you think you can achieve that by April the 15th?

Mr. BRIDENSTINE. I think we can get really close, yes, ma'am.

Chairwoman JOHNSON. OK. Thank you very much. My time has expired. Mr. Lucas.

Mr. LUCAS. Madam Chair, before I begin my official question time, I'd like to ask to speak for a moment out of order and introduce a new Member to the Committee.

Chairwoman JOHNSON. Yes.

Mr. LUCAS. Thank you, Madam Chairman. Jaime Herrera Beutler represents the Third District of the southwest of Washington State. She's done great work already on advancing STEM conserving important resources and driving technology progress, so welcome to the Committee, Jaime. You'll find this is a fun Committee, and that's not always the circumstances everywhere.

Thank you, Madam Chairman.

Chairwoman JOHNSON. Thank you and welcome. And when you mentioned STEM in any of your conversation, you get my attention, Mr. Lucas.

Mr. LUCAS. Well put, Madam Chair.

Director, this FY2020 budget request for NASA is $21,019,000,000 and change so to speak. The Obama Administration's last request for FY2017 planned to request $19.879 billion in FY2020. How does the extra $1.14 billion request scheduled for this year enable exploration in science and aeronautics? What's the difference between the two?

Mr. BRIDENSTINE. So the focus now is getting humans to the moon as soon as possible. 2028 was based on the budget request, and the intent of course is to not just get humans to the surface of the moon but prove that we can live and work on another world. And that's really what the extra resources have been applied to.

Mr. LUCAS. Continuing down that road, the budget request proposes delaying continued development of the exploration upper

stage for the Space Launch System that, along with advanced boosters, is necessary to meet the congressional directive to develop a 130-metric ton launch vehicle. Why is NASA delaying that effort on the capacity?

Mr. BRIDENSTINE. Mr. Ranking Member, what we have found is that the development of SLS has proven to be more challenging than previously anticipated, so what we have attempted to do at NASA is focus Boeing on getting the core stage of SLS complete, and then from there we can move to the exploration upper stage. But the key is to be able to launch American astronauts to the moon, and we can do that with an SLS core stage and an interim cryogenic propulsion stage, and then we can get to that near rectilinear halo orbit around the moon where we're going to build the Gateway.

But the key is it—and I agree with you completely—we need an exploration upper stage. The key is we've got to get the SLS built or the exploration upper stage isn't going to be usable.

Mr. LUCAS. So we're still committed to developing the 130 metric ton launch vehicle?

Mr. BRIDENSTINE. Yes, sir. In this——

Mr. LUCAS. Because if we're going to throw big things up, we've got to have a big capacity to do that.

Mr. BRIDENSTINE. Yes, sir. In this budget request the intent was to delay. We are—we have no intent to cancel. We're trying to get SLS complete so we can get humans in the vicinity of the moon as soon as possible.

Mr. LUCAS. Director, 2 years ago Congress passed the *Weather Research and Forecasting Innovation Act*, which I sponsored, and featured yourself and Ms. Bonamici as the original cosponsors. Title III of the act created a pilot program for NOAA (National Oceanic and Atmospheric Administration) to procure data from the private sector that could be integrated into the National Weather Service forecast. The law also directs NOAA to avoid duplication between public and private resources of data. The goal was to stimulate the private sector to provide data to protect lives and property and ensure U.S. leadership in weather forecasting.

The FY2020 budget request for NASA proposes to spend millions of dollars on sensors aboard the European Sentinel-6 mission to conduct Global Navigation Satellite System radio occultation observations to ingest into the U.S. forecast. U.S. companies are currently providing GPS radio occultation data to NOAA. This Administration and you in particular have been stalwart advocates for commercial space enterprise. How is NASA ensuring they're not competing with the private sector aside from the direction in the *2017 Weather Act*? Current U.S. commercial remote-sensing policy also directs agencies to rely on maximum practical extent on U.S. commercial remote-sensing space capacities for fulfilling imagery and the needs of the military, intelligence, foreign policy, homeland security. How are we balancing that public-private?

Mr. BRIDENSTINE. Sir, this is a critically important issue that our Nation needs to be focused on. As you are aware, GPS radio occultation, under laws passed by this Committee and this Congress, have enabled us to, for the first time in history, use commercial GPS radio occultation data and ingest it into our data assimilation

systems and our numerical weather models and in fact derive results that are meaningful. In other words, commercial data is no longer going to be really just a pilot program, but we're looking to operationalize that commercial data because of the work of this Committee. And for that I will tell you our Nation is grateful.

As far as the operational use of GPS radio occultation data from our European partners, NASA is not involved in that. I would defer to my NOAA colleagues on how they intend to I guess work that issue. But know that commercial data is a critical piece of the mix, and I'm happy to take that and get you a more complete answer after talking to my NOAA colleagues.

Mr. LUCAS. We'll follow up because we certainly don't want to push private industry out of the spectrum, as hard as you and I worked to make that possible.

Mr. BRIDENSTINE. Yes, sir.

Mr. LUCAS. With my remaining moments, Madam Chairman, I have the privilege of also introducing one more new Republican Member of the Science Committee. Jenniffer González-Colón represents Puerto Rico, which has a large R&D industry and a commitment to innovation and research. is also a proud graduate of a STEM magnet high school, and she's told me she's excited to work on promoting STEM education. So you have another ally, Madam Chairman, when it comes to STEM.

Chairwoman JOHNSON. Thank you very much. They can keep on coming. Thank you.

Mr. LUCAS. I yield back, Madam Chairman.

Chairwoman JOHNSON. Thank you very much. Ms. Bonamici.

Ms. BONAMICI. Thank you so much to the Chair and Ranking Member, and welcome back to the Science Committee to our former colleague Administrator Bridenstine.

Mr. BRIDENSTINE. Thank you.

Ms. BONAMICI. I appreciated our early efforts to work together, and thank you, Mr. Lucas, for pointing that out, and I hope we can continue to work together to support NASA and its historic mission and its workforce.

And I understand you have many priorities to balance when writing the fiscal 2020 budget request. I say I'm disappointed to see a shift away from the multi-mission role, which seems to be contrary to congressional intent in recent reauthorizations and appropriations to restore funding to NASA's Science Mission Directorate. NASA has some of the very best scientists in the world, and as we face the consequences of climate change and extreme weather patterns, we should be doing everything we can to leverage information from Earth-observing satellites to strengthen our understanding of climate change and identify successful adaptation and mitigation strategies.

And as the Co-Chair of the House Oceans Caucus, I'm also glad to welcome the new Members who have districts that are definitely affected by ocean health. I know that the health of our natural resources, specifically marine resources, is critical. Warming waters have been triggering harmful algal blooms, which cause a serious problem to marine life and human life and our economy as well, and investments in research to predict and adapt to those challenges is important.

So I'm looking at NASA's PACE mission, the Plankton Aerosol Cloud and Ocean Ecosystem mission, that could help us understand algal blooms and their relation to other environmental events, for example. So that's scheduled to launch in 2022 and will improve NASA's satellite observations of ocean ecosystems and the atmosphere.

However, Administrator Bridenstine, despite demonstrated value shown in the January 2018 National Academies' Earth Sciences Decadal Survey, the "Thriving on Our Changing Planet" survey, your budget proposes to terminate the PACE mission and justifies this decision by stating that existing and planned missions from other NASA, NOAA, and international partner satellite fleets are providing or will provide measurements to establish similar science. It's worth noting that the PACE mission is known for having the most advanced ocean color instrument in NASA's history.

So what are the other Federal Government and international satellite efforts that are providing or you say will provide similar results? And is there a consensus from the scientific community that the same data products of the same quality that would have been in the PACE mission will be delivered from other missions? And did you consult with other scientific researchers involved with PACE before making this decision?

Mr. BRIDENSTINE. So that's another important question. Know this, Congresswoman, as of right now, PACE is funded by Congress, and we are moving out on it very rapidly. It is a good mission, and NASA believes in it, and we're working very hard to achieve its launch in 2022.

It is also true that it's early in the development phase, and when we consider all of the things that we're balancing, that was one of the casualties of ultimately making decisions in a constrained, you know, budget environment. But it is also true that there are other missions that NASA has and our international partners have that help us characterize the color of water. Specific missions that, you know, I can take that for the record and get back to you what those instruments may be and on which satellites and——

Ms. BONAMICI. And did you consult with the scientific researchers involved in the PACE mission when making this decision to terminate the program?

Mr. BRIDENSTINE. We did. We consult with all of our missions when making these critically important decisions.

Ms. BONAMICI. I have another question. Last Congress, we passed the *NASA Transition Authorization Act* reaffirming the sense of Congress that the Administrator should set science priorities by following the guidance provided by the scientific community through the National Academies of Science Engineering and Medicine's Decadal Surveys. And I'm concerned that the proposed budget does not align with this principle, especially concerned about cuts to Earth science. Can you explain the lack of funding in your budget request to initiate missions and implement the most recent Earth science decadal survey? And based on your fiscal 2020 request, when could we expect decadal surveys' missions to be initiated and launched and when will they be funded?

Mr. BRIDENSTINE. Yes, ma'am. So as of right now we have the highest Earth science budget in the history of the United States,

and if you look at our Earth science budget compared to that of all the other nations of the world, if you add up the European Space Agency and Canada and Japan and Russia, our partners on the International Space Station, collectively their GDPs are higher than ours, and we're about equal to spending as much as all of those nations combined on Earth science.

I think our Earth science budget is very good. In fact, this particular Earth science budget request is higher than five of the budgets that were enacted under President Obama, which is a solid I think position to be in. And I know you and I have talked. My commitment is and will be to do everything possible to make NASA an apolitical, bipartisan organization. I want to drive consensus. And the way we get consensus is to listen to the decadal surveys from the National Academy of Sciences. And to the best of my ability I have done that, and my commitment is to continue doing that.

Ms. BONAMICI. Thank you. My time is expired. I yield back. Thank you.

Chairwoman JOHNSON. Thank you. Mr. Posey.

Mr. POSEY. Thank you, Madam Chair and Ranking Member, for holding this hearing. It certainly is good to know that our days of reliance on others for human access to space are limited.

And great to see you back here, Mr. Bridenstine, as Administrator.

Mr. BRIDENSTINE. Thank you.

Mr. POSEY. Can you provide an overview of what preparations are being made at Kennedy Space Center to support the first launch of SLS and Orion on an Exploration Mission-1 (EM-1) next year as we prepare to receive and process the rocket and the spacecraft at KSC (Kennedy Space Center)? What activities are taking place now to ensure that smooth stacking integration and rollout will all happen?

Mr. BRIDENSTINE. Absolutely. So at Kennedy the exploration ground systems are key. Of course, having a mobile launcher is key. Those are under development and getting very close to being ready. The first SLS we have had some delays with, as I've already explained. That's why we're so focused on it. In order to achieve getting that SLS to Kennedy as soon as possible we've made some significant changes in how we're actually developing it. We have found that—and we did not know this ahead of time. We have found that the engine section of the SLS is actually on the critical path because of the complexity that was unanticipated, and the challenges the rest of the SLS rocket was dependent on that section being complete before it could be integrated. And that was based on a property plant and equipment limitation that we had.

So what do we do? We've now purchased new equipment—I should say new tooling so we can start integrating the oxygen tank or the hydrogen tank with the intertank and fairings. We can actually do that in the horizontal while we're continuing to work on the engine section, so that's accelerating the path. And of course once that is complete, we will do testing on the entire integrated vehicle through what we call a green run. We're making determinations right now ultimately how much of a green run we need to do based on the schedule that we are attempting to achieve.

And I want to be clear; we're going to be very safe. We're not going to do anything that brings undue safety. But if there are things that we're testing that are nice to have and not necessary, then we're going to look at moving those to a later test.

But at the end of the day we want to get the rocket to the Kennedy Space Center. We want to make sure that the launchpad and the mobile launcher are ready to go, and all of those are not in the critical path right now. I think we're in good shape for those activities, and I can tell you everybody at Kennedy is extremely excited about getting the first launch of SLS by 2020. And that's what we're working on right now, getting it by the end of 2020.

Mr. POSEY. Well, thank you very much for your direct answer. And I appreciated your comments last week about the importance of the exploration upper stage for the SLS, the second mobile launcher——

Mr. BRIDENSTINE. That's right.

Mr. POSEY [continuing]. That will launch a more powerful rocket by Exploration Mission-3. These upgrades will allow SLS to launch both astronauts on Orion while also carrying the large payloads, lunar landers, and so forth.

Although NASA's Fiscal Year 2020 budget process proposes deferring the work until several years out, it appears that, based on the Vice President's charge, that we accelerate the return and the immediate development. And your comments all seem to jive. And so, if so, you know, how will NASA continue and accelerate EUS (Exploration Upper Stage) and ML2 (Mobile Launcher 2) development——

Mr. BRIDENSTINE. Yes.

Mr. POSEY [continuing]. In FY2020?

Mr. BRIDENSTINE. So just so you're aware, this is an important issue, and you're hitting the nail on the head. Under the law, we are required to build the second mobile launcher. And what we do at NASA is we follow the law. So we are right now—in order to build that second mobile launcher, which is required by law, we are continuing to develop the exploration upper stage in a limited way. Like I told Ranking Member Lucas, we want to focus on that core stage, but in a limited way we need to continue development on exploration upper stage so that we can follow the law and build that second mobile launcher. My commitment, sir, is to follow the law, and we will continue doing that.

But it is true that right now if we're going to accelerate the agenda to 2024, we're going to have to make decisions as to what the level of investment is going to be and make a modification to the budget request to achieve that agenda. And we look forward in the coming weeks working with OMB (Office of Management and Budget) and the Administration coming to you with a plan to achieve that, and that's—like the—or like the Chairwoman said—I keep going back to my old days. Like the Chairwoman said, we want to get that to you as soon as possible hopefully by April 15th.

Mr. POSEY. Thank you very much, Mr. Bridenstine, and I yield back.

Chairwoman JOHNSON. Thank you very much. Ms. Horn.

Ms. HORN. Thank you, Madam Chair.

Good morning, Administrator. I want to start by saying I have a statement that I've submitted for the record that should be over there.

I want to start off by talking—I think you made a good point about this is not a partisan issue, and it shouldn't be, but I think there are some important unanswered questions about how we're going to achieve the things that have been proposed and some clarity. So in the congressional justification for the FY2020 request, it states that NASA's Orion spacecraft and Space Launch Systems are the backbone for deep space exploration from which private companies could one day provide equivalent commercial. I think the conversation about the appropriate balance between government and commercial is critical.

But at the Senate Committee hearing, you mentioned that you are considering the use of commercial vehicles to launch Orion on an EM-1 mission. So in your prepared statement for today's hearing you also said that NASA is also assessing alternative architectures for the EM-1 that could include the use of commercial launch vehicles, but at the same time on March 26 in a press release you were quoted as saying that, "while some of these alternative vehicles could work, none was capable of achieving our goals in orbit around the moon for the EM-1 within our timeline and on budget. The results of this 2-week study reaffirmed our commitment to SLS."

So I guess given these conflicting statements, can you tell me what the final decision was on that?

Mr. BRIDENSTINE. Absolutely. So the answer is the 2-week study is complete, and we looked at all of the commercial options, and we took nothing off the table. If—what is the realm of possibility and how do we achieve a 2020 launch with an Orion crew vehicle and a European Service Module? We looked at a Delta IV Heavy. I don't know—I don't want to take up all of your time, but we looked at a Delta IV Heavy. It doesn't have the throw-weight. With an ICPS (interim cryogenic propulsion stage) at the top, it gets even heavier and it still can't make it to Earth orbit.

So then we said, well, what about two Delta IVs? The challenge there is you have—we only have one launchpad on each coast. If you launch from the West Coast, you have to launch south, which means you have to, you know, change orbits once you're there. A lot of Delta V, a lot of time, cryogenic boil-off, it doesn't work. So then we said what about launching a Delta IV and a Falcon Heavy? What if we were to put a Crew Dragon on top of a Falcon and do automatic rendezvous and docking, which is the only capability we have right now as a country is that Crew Dragon to do automatic rendezvous and docking with the Orion? The challenge there is the Crew Dragon doesn't have the thrust to throw the Orion around the moon, so that didn't work.

So then we looked at way out of the box—what if we were to consider putting a Falcon Heavy with an Orion service module or the Orion crew vehicle and a European Service Module and an ICPS from ULA? I know that sounds crazy, but again, we're looking at all options. And in fact it works. It requires a lot of modifications to the launch infrastructure, to the launchpad, to the erector arm. It takes a lot of modifications to do cryogenic and hypergolic refuel-

ing on the pad, which doesn't currently exist. There—it takes a lot of time and there's a lot of cost and there's risk, and it wouldn't work for accelerating a 2020 launch of an Orion crew vehicle.

But what it did demonstrate is that if you have a little bit of extra time, 2023, maybe 2024, a lot of that uncertainty could be retired. And if we're going to get——

Ms. HORN. So just because I have a few more questions——

Mr. BRIDENSTINE. Yes.

Ms. HORN [continuing]. That I want to get to. So can you boil it down to the final decision? Because I appreciate you looking at all those things, but can you boil that down to the final decision that we're still on track——

Mr. BRIDENSTINE. The——

Ms. HORN [continuing]. With the SLS for EM-1?

Mr. BRIDENSTINE. Absolutely.

Ms. HORN. OK.

Mr. BRIDENSTINE. SLS is the best—in fact it's the only option for EM-1, and there are options in the future that need to be considered. And when we land on the moon in 2024, it's only——

Ms. HORN. OK.

Mr. BRIDENSTINE [continuing]. Because of an all-of-the-above strategy.

Ms. HORN. There's a couple more questions I have, and I'm just going to boil them down really quickly. Actually, I've got quite a few more. But focusing on the accelerated moon landing and how we're going to get there moving it up even another 5 years from where we were, there are with these announcements and moving it up, what is the need for the lunar demonstration programs given this proposed accelerated timeline? How are those programs going to be impacted?

Mr. BRIDENSTINE. They're important. So, you know, we have the commercial lunar payload services underway where we are going to purchase the access to the moon commercially. We're going to—you know, small payloads, 10 pounds or less, can you deliver it to the south pole of the moon so we can characterize the water ice, understand kind of what is the value of the specific territory where we want to land? So those missions are underway right now. They're critically important to helping us understand where—when we land humans on the surface of the moon, where we want to place those humans.

Ms. HORN. OK. My time is expired, but we'll be submitting some more questions for the record. Thank you.

Mr. BRIDENSTINE. Yes, ma'am.

Chairwoman JOHNSON. Thank you very much. Mr. Balderson.

Mr. BALDERSON. I apologize, Mrs. Chair. I didn't hear you.

Good morning.

Mr. BRIDENSTINE. Good morning.

Mr. BALDERSON. My first question to you would be the FY2020 budget request calls for the elimination of NASA Office of Education. I believe that we need to be encouraging hands-on STEM education, which NASA has supported in the past. Could you elaborate on how NASA will continue to support STEM education while zeroing in on the education account?

Mr. BRIDENSTINE. Absolutely. So NASA does this all the time through the various mission directorates. NASA does it all the time through the various centers across the agency, and we do it when we partner with universities, with, you know, critically important projects and programs for the agency and our exploration mission and our planetary science missions.

So we have a broad kind of STEM agenda that is funded in a whole lot of different ways. That specific Office of Education is a small piece of everything that we do. I can give you an example. A couple of weeks ago I was at a FIRST (For Inspiration and Recognition of Science and Technology) Robotics event, and there were thousands of kids there. NASA sponsors it to the tune of about $4 million annually. Why? Because if you look at the people that are building our robots that are currently on Mars, they were participants in FIRST Robotics when they were coming up through school. So that's an amazing program that has paid dividends for NASA and in fact for the country.

And so what we like to do is focus on areas where we know we're getting a return for the agency and a return for the country. And, again, given the constraints of the budget, we've decided to focus on those areas.

Mr. BALDERSON. OK. Thank you. I have one more question. In your testimony you talk about the importance of the Lunar Gateway in order to continue manned missions beyond the low-Earth orbit. I think it's important to recognize the hard work being done at NASA at the Glenn Research Center, which is just north of my district in Ohio. My team had the chance to tour the facility that is working on the development of the power propulsion element at NASA Glenn, and found the work to be fascinating. Could you talk about the importance of work being done at research centers around the country?

Mr. BRIDENSTINE. Absolutely. And that power and propulsion element that's going to be part of Gateway, when we talk about Gateway, some people think of it as like a space station in orbit around the moon. It's very different. This is in fact—it's a reusable command and service module that is going to enable our astronauts and our robots and our landers and rovers—it's going to enable us more access to more parts of the moon than ever before. And the reason that's possible is because of that power and propulsion element, solar electric propulsion at thrust values that are greater than we've ever been able to achieve before with solar electric propulsions. That's very high specific impulse. It means that the fuel is going to last a long time. The goal is for the Gateway to remain in orbit around the moon for a period of 15 years to be able to go from that near rectilinear halo orbit all the way up to the L1 point and the L2 point, which enables all of our capabilities to get to more parts of the moon than ever before. So that power and propulsion element is critical.

Mr. BALDERSON. Thank you very much.

Madam Chair, I yield back my remaining time.

Chairwoman JOHNSON. Thank you very much. Mr. Perlmutter.

Mr. PERLMUTTER. Thank you, Madam Chair.

And, Mr. Bridenstine, thanks for being before our Committee today, and it's good to see you.

Initially when I came in, I was disappointed in the report that came back on the pathway to Mars because they basically said, well, given the constraints that NASA faces and budget and all this stuff, we don't think we can get there for a long time was more or less what they said, which really was disappointing to me. And, quite frankly, I was very encouraged by your initial comments to the Chairwoman about the desire to get to Mars by 2033. And I don't mean to be a one-trick pony on this, but I think it drives a lot of other conversations.

And so, you know, it's a responsibility of the Congress to provide you all with the resources, and the pressure that you felt from the White House and—not you but NASA to accelerate returning to the moon, you know, being able to survive on the moon for extended periods of time, quite frankly for me I'm OK with that because I think it accelerates the effort to get to Mars, which I think is the underlying driving force here for inspiration, as well as for NASA to just really expand and continue to expand its capabilities and its imagination.

So I really don't have too many questions. My responsibility is to continue to talk to this Committee and to others about this goal.

Something that's interesting—and this is sort of outside the context of this Committee—is when Vice President Pence says we're in a space race or we've got competition, there's an element of national security that is attached to that somewhat. It's not just a civil side of our budget that is implicated in that. And so I'm going to be turning over every stone to provide the resources so that the technical, the science, all that stuff to get this done. And I'll just have an open-ended statement to you about that, and you can respond.

Mr. BRIDENSTINE. I will tell you, Congressman Perlmutter, your leadership on this has been amazing. In fact, when I came over here, I said, look, I'm going to see my friend Ed Perlmutter, and I need to get a bumper sticker that says 2033 on it. I didn't have one in my office. I don't know why I didn't have one in my office; I should have. But I walked into an office just down the hall, and I stole one from somebody who works at NASA. So just know that your efforts have been felt and seen and heard throughout NASA, and we're grateful for it, and we are doing everything we can to accelerate that agenda because you're right; Mars is in fact the horizon goal. The moon is the tool that we need to get to Mars.

The glory of the moon is it's a 3-day journey home. We have seen what happens when there's failure on the way to the moon with Apollo 13. People can make it home safely. If that were to happen on the way to Mars, it would be a very bad day for the country, and we don't want that to happen, so the moon is the tool to get to Mars, and we're doing everything we can to accelerate.

Mr. PERLMUTTER. Thank you. I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Gonzalez.

Mr. GONZALEZ. Thank you, Madam Chair and Ranking Member, for holding this hearing today, and obviously a big thank you to you, Mr. Bridenstine, for your work for our country and with NASA.

So, like Troy, I represent northeast Ohio. He's central Ohio. And we're home to the NASA Glenn Research Center, as you know, a

quintessential research center for achieving NASA's vision and mission. Having visited the center recently, I saw firsthand just how incredible the scientists are, the engineers, the technicians working there, over 3,000 strong, just absolutely amazing work.

As you may know, the midwest has suffered from the loss of manufacturing jobs over the last decade. Look no further than our recent closing in Lordstown at the GM plant. It's my belief that in recent years, certainly with the Glenn Research Center, NASA has underutilized the commercial aerospace resources and human capital of Ohio and nearby States. What can you do or think about to ensure that midwest's capabilities and capacities are recognized in the procurement and development of goods and services obtained by NASA?

Mr. BRIDENSTINE. That's another very important question. We are working every day at NASA to make sure that we're taking advantage of all of our centers and all of the talent that we have, and we always consider the talent internal to our agency before we go outside the agency. And what you—you know very well, as—we have a lot of talent. The power and propulsion element, as we just discussed, is a critical piece of the future architecture, but the aeronautics capabilities of Glenn are really second to none. We're talking about wind tunnel technologies, we're talking about the ability to test engines, to increase fuel efficiency, to in fact, you know, improve, you know, the environmental standards of aircraft. All of these things are being done at Glenn in a very meaningful and positive way, and they have implications for our country.

When we talk about exports, when we talk about how important our engine manufacturing is around the world, we are able to maintain this very cutting-edge capability in the propulsion sector of the aviation market because of the efforts of people at Glenn and other research centers throughout NASA.

Mr. GONZALEZ. Thank you. And then shifting gears, in your testimony you highlight the importance of aeronautics and U.S. leadership in the global industry. As Russia and China continue to make investments in their domestic aerospace sector, I think it's more critical than ever that NASA continue to lead in the fundamental research that will help the U.S. aerospace sector remain competitive, especially in commercial aircraft and autonomous passenger and cargo systems. Administrator, can you talk about how important the aeronautics research that NASA conducts is to our aviation economy and how NASA can better position itself to ensure the U.S. is a leader in aviation research, so kind of take a strategic lens on it if you could?

Mr. BRIDENSTINE. Absolutely. So we—what we have to think about is what does the future of aviation look like and how does the United States of America remain preeminent in that space really for our own economy and for exports? And that's really where NASA plays. There are some very leading-edge investments that might be too high-risk for a for-profit company to invest in, but we can come alongside and support them in that effort, and we've done that. I don't know if you—if you look at engines these days on aircraft and, as a pilot, I look at these engines I'm like, man, these engines keep getting bigger and bigger and the point now where the engines are flat on the bottom because they'll hit

the ground, that kind of thing, what is driving that? Well, these are reduction gear capabilities developed by NASA with partnerships with our commercial industries ultimately so that we can increase fuel efficiency, reduce noise, and have better environmental standards without losing any kind of power or thrust. So those bigger turbofans are a direct result of NASA investments, and we want to keep doing that.

It's also important to note a couple of other things I think are important. We want to be able to fly from New York to L.A. in a matter of 2 hours instead of 6 hours. We want to have an ability to fly supersonic across the United States without a sonic boom that is disturbing to people and infrastructure. That technology is being developed right now so that at the end of the day FAA (Federal Aviation Administration) can give us a determination that it's perfectly OK to fly supersonic over the United States. We're working on that.

And then when we think about urban air mobility, the idea that you can order something and have it delivered to your front door with, no kidding, a drone in a matter of minutes, that capability is on the horizon, and eventually the idea that we're going to be able to fly humans across a city and avoid traffic with urban air mobility, like we need to be thinking about that today.

There's billions of dollars of investment going into these activities all over the world. The United States of America needs to be in the lead.

Mr. GONZALEZ. I completely agree with you. Thank you for your time, and I yield back.

Mr. BRIDENSTINE. You bet.

Chairwoman JOHNSON. Thank you very much. Dr. Foster.

Mr. FOSTER. Thank you, Madam Chair, and thank you, Administrator. Let's see. One quick question on the 2024 launch date. Who made that decision to change it by 5 years?

Mr. BRIDENSTINE. That was a decision by the President of the United States announced by the Vice President of the United States.

Mr. FOSTER. Fascinating. OK. Were technical people consulted——

Mr. BRIDENSTINE. Yes.

Mr. FOSTER [continuing]. And budgetary people consulted?

Mr. BRIDENSTINE. Yes.

Mr. FOSTER. And was the question asked what that would do to the budget at the time that the command was given?

Mr. BRIDENSTINE. The determination was made that we would need to make an amendment to the budget requests, and we're working on that right now.

Mr. FOSTER. And you're doing that on a zero-sum basis or are you going to be allowed to increase the total for NASA or are you going to have to cut other programs?

Mr. BRIDENSTINE. Oh, I will tell you it will not be successful if we're cutting other programs because we have to have bipartisan support.

Mr. FOSTER. And so you will be asking for an increase. And was it specified who would be taxed to do that?

Mr. BRIDENSTINE. Will there be taxes to do it?

Mr. FOSTER. Yes, taxes. If you're going to increase the budget, normally you have to tax someone to pay for it or to specify what else you're cutting.

Mr. BRIDENSTINE. That would be a determination by somebody other than the NASA Administrator.

Mr. FOSTER. OK. All right. Now, you're talking about, you know, essentially a program based on chemical rockets that would be completely understandable to Werner von Braun, everything you're proposing. And there have been for, you know, decades conceptual designs for ways to get stuff into low-Earth orbit for much less. And, you know, for example, you know, these are things like electromagnetic launch systems, air breathing systems, space elevators, Lofstrom loop, all this sort of stuff, and it seems like you're spending a negligible amount on stuff that actually has a chance to reduce the cost of getting stuff into low-Earth orbit. And is that something that bothers you or have you considered moving the needle on that so that actually we have a chance 50 or 100 years from now with having space be affordable to people, which I think it's pretty clearly not going to happen when—if we just keep using chemical rockets again and again?

Mr. BRIDENSTINE. That's an important question. You're absolutely right; chemical rockets are expensive. We're making really great advancements right now on the reusability of rockets, which is driving down cost and increasing——

Mr. FOSTER. But that's not a major effect. You know, I visited SpaceX, you know, when they were—this was still conceptual and hadn't been proven yet and I asked the question, OK, if you reuse the booster, you know, let's say it all works and that they're able to do it, you know, and you reduce your capacity to low-Earth orbit because you have to retain fuel to land the booster, you have to go and take stuff apart and re-space—qualify it, and everything. How much money do you actually save? And the answer from the engineer at the time was you save 17 percent. That is not transformative. We need a factor of 10 in the reduction of cost, not, you know, whatever number you get from reusability of the first-stage booster. So you have to spend money on transformative technologies, and I don't see that anywhere in your budget. How do you view that tradeoff?

Mr. BRIDENSTINE. So I think—again, I think it depends on, you know, what your definition of transformative technologies are. I will tell you——

Mr. FOSTER. Something that could factor of 10 in the cost to low-Earth orbit, OK?

Mr. BRIDENSTINE. Well, if there's a way to get a factor of 10 reduction in cost, I'm all for it, and I'd love to hear your ideas on it. I know you're a physicist, and I'm all ears.

Mr. FOSTER. It relies on fundamental research. If you want to make the space elevator work, you've got to get long carbon nanotubes in mass production. You know, these are things where—they're good ideas on how to spend the money, but if you concentrate more and more on let's go to the moon with the exact same technology we used 50 years ago in the next 5 years, the money that's spent there is not being spent on something that could actually make space accessible to large numbers of Ameri-

cans 20, 30, 50 years from now. So I urge you to rethink the trajectory you're on.

And in a similar way space nuclear power is something that you're working on, and the decision that you have to make early is whether you're going to use weapons-grade material or non-weapons-grade material. So I understand that for nuclear space propulsion you have settled on low-enriched non-weapons usable, and—that's correct, yes.

Mr. BRIDENSTINE. That's what—yes, we currently——

Mr. FOSTER. Right.

Mr. BRIDENSTINE [continuing]. Use, yes.

Mr. FOSTER. On the other hand, it appears you're not heading in that direction at least initially for space power reactions—reactors. So these are things that would be used potentially on satellites, potentially on lunar or Mars spaces.

Mr. BRIDENSTINE. Sure.

Mr. FOSTER. And, you know, a future where every spacefaring nation has a big inventory of weapons-grade material to service the reactors that they are using all over the moon and all over Mars is not a very safe space environment. And I've spent some time looking into it. There will be some small performance compromises in going with low-enriched non-weapons-grade material that I really urge you to look hard at keeping alive the prospect of having an international collaboration to develop workable non-weapons-grade-based materials that the whole world will use.

Mr. BRIDENSTINE. I will look at those options.

Mr. FOSTER. Thank you. I appreciate that.

Chairwoman JOHNSON. Thank you very much. Mr. Cloud.

Mr. CLOUD. Hello.

Mr. BRIDENSTINE. Oh, hey, there you are.

Mr. CLOUD. Good to see you.

Mr. BRIDENSTINE. Good to see you.

Mr. CLOUD. Thanks for being here. You certainly probably have the funnest job in the room.

Mr. BRIDENSTINE. I agree.

Mr. CLOUD. And it's certainly exciting what's going on in space right now. Not only is it exciting, it's necessary and noble, the work that's being done. NASA certainly is part of our national heritage, and what's going on is necessary.

This renewed space race is certainly essential not only from the exploratory side of science and those kind of things but from a national security standpoint when we see China and all they're doing to take the high ground. And an information economy, who controls space controls the information, and it's just essential of course that we continue to lead in that front.

My question has to do with if you talk to the Government Accountability Office—GAO, they have NASA on the High-Risk List for waste and have actually downgraded them—now, this is what you walked into. I'm wondering what we're doing because as we prioritize how important it is to spend the certain levels of money, I think it's just as important that we prioritize the efficiencies. Can you speak to what NASA is doing to create efficiencies and especially, you know, in the sense of being more efficient than China in winning the space race?

Mr. BRIDENSTINE. Absolutely. So you're absolutely right. The GAO High-Risk List has NASA on it, and yes, we have been downgraded. So the reason we're there is because we have not been good at maintaining schedule, and we have not been good at maintaining costs. Now, there's a number of reasons for that, and I think people on this Committee are well aware. What we do is unique. It's unlike anything that any other agency does. We build things that have never existed before, and we have to invent things to make our products work, things that are really, quite frankly, astonishing and stunning.

So I'm not making any kind of excuse. We need to be much better at making determinations as to the cost of what we're going to build and the schedule of what we're going to build. Part of that requires us to ultimately not be so aggressive in what we say we can achieve. We need to make sure that we have margin built into our schedules and into our cost as a matter of fact.

NASA is very ambitious as an agency. It's a culture that in fact is a—it's kind of a good thing. Everybody wants to work really hard to achieve just amazing and astonishing things and do it yesterday, but sometimes we need to be more realistic, and that's part of what we're trying to get fixed. When we have schedule delays, whether it's commercial crew or SLS or exploration upper stage, whatever the case might be, those delays ultimately put—it puts us as an agency at risk, and it encourages Congressmen to ask questions that we don't like to answer. So we've got to get better at making those assessments, and we're working on that.

Mr. CLOUD. I think of, for example, there's an Israeli space company landing—or in the next few weeks we think will land——

Mr. BRIDENSTINE. Yes.

Mr. CLOUD [continuing]. On the moon, the first commercial company, what's going on in the commercial industry. Can you speak to ways that NASA is partnering with it, maybe——

Mr. BRIDENSTINE. Absolutely——

Mr. CLOUD [continuing]. Is that one way to save money? And also——

Mr. BRIDENSTINE. Yes.

Mr. CLOUD [continuing]. For example, the XPRIZE, that Israeli company was motivated by an XPRIZE. Is NASA doing that kind of thing when it comes to contracting to maybe take the burden of research off some of these things and put it in the innovators——

Mr. BRIDENSTINE. Yes. Here's the challenge. Sometimes the companies have an incentive to overstate what they can achieve as well because they're all trying to win contracts in that particular case, so we have to be careful about—in other words, we as an agency not only need to be good at managing our own programs, we have to be really good buyers. We have to be smart buyers. And in fact I would argue that it could be said that, as we have turned more to commercial industry to provide capability, we have lost in some cases the intellectual capital necessary to be a smart buyer.

So on one hand, yes, you're right, we can outsource some of those challenges. On the other hand, we still have to meet schedule and we still have to meet cost, and we can't rely on somebody else to tell us what that schedule and cost is because sometimes they're

not right either, and then we're held accountable for it. So we have to be careful with how we go about that in the future.

But the XPRIZE, you mentioned SpaceIL, we are partnering with SpaceIL, which is that little Israeli company. They're going to be landing something on the moon for $95 million worth of investment, which is a radical change in cost for anything that's ever landed on the moon previously. NASA is a partner with them on an instrument that's on that vehicle. We are also providing our deep space network to support them with communications, which is unique to us. So we're a partner with them. We're proud of that.

And we have our own program domestically for commercial lunar payload services where we're going to have—we've already signed up nine companies that are able—that we have assessed are able to deliver small payloads to the surface of the moon, and we're looking forward to—when in fact we have already put out the first task order and we're looking forward to seeing what industry is going to be willing to provide from a domestic perspective as far as landing small payloads on the surface of the moon.

All of these things are critical capabilities, and in some cases they help us with the GAO high risk report. In other cases, it could actually put us in more risk. But we have to be more careful about how we go about telling you and others about our schedule. As much as we want to tell everybody were going to get there yesterday, we need to be really careful about that.

Mr. CLOUD. Thank you.

Chairwoman JOHNSON. Thank you very much. Mr. McAdams.

Mr. MCADAMS. Thank you, Madam Chair, and thank you, Administrator Bridenstine, for your time and for your testimony to the Committee here today.

NASA enjoys an incredible reputation with the American people, and myself as well, and I'm excited to hear more about the inspiring plans for the future of our Nation's space program. It's been an interesting and informative dialog today.

Utah, my home State, has a proud heritage of supporting human space exploration as well from the building of the reusable solid rocket motors that boosted the space shuttles' 135 launches from 1981 through 2011 to the updated versions being produced for the Space Launch System or SLS to take us back to the moon and beyond, as we've been discussing today.

I also believe that I share with you the belief that we must ensure our priorities are informed by the scientific community's knowledge and priorities for exploration and technology development and that our goals, which certainly must be ambitious as they are, are also grounded in our ability to deliver the requisite technology and safely complete the missions.

So my question for you is, first of all, I guess I'm a little perplexed that after NASA prepared the agency's budget request, the Administration announced an acceleration, the acceleration of the plans to send humans to the moon again by 2024 rather than the previous goal, a goal that I support. And while I think that objective is laudable, I'm concerned that given what appears to be a lack of planning for such a goal that NASA still has a lot of questions to answer to achieve that mission on such a short timeframe.

So I'm also pleased to hear your ongoing commitment to the SLS, but how would this budget speed up SLS development and readiness, particularly in light of its important role in the accelerated mission schedule?

Mr. BRIDENSTINE. So the budget request currently has us focused on the core stage of SLS, which is where the challenge has been, specifically the engine section on that core stage, and so we are using the resources that we have for the SLS focused on that. And we have in fact made tooling investments so that we can integrate the oxygen tank, the inner tank, the hydrogen tank in a horizontal way so the engine section is no longer in the critical path and we can continue assembling the rest of the rocket for a delivery by the end of this year. So all of that I think is progress in the right direction. And—you had a question ahead of that. What was——

Mr. MCADAMS. Yes, just how—in light of the—sorry, let me just look back at my notes here.

Mr. BRIDENSTINE. Yes.

Mr. MCADAMS. Well, I guess I had—a follow-on question that I would have, has this accelerated schedule—you discussed that with the Aerospace Safety Advisory Panel and what comments or concerns did they have if any?

Mr. BRIDENSTINE. So that's a—the answer is that we have discussed this. I had a townhall yesterday. We got questions about it with the entire NASA family and put it all out there and said, look, we have a new agenda to get there in 2024, and of course there were questions like are we going to compromise safety. And the answer is, Congressman, absolutely not. We have independent technical authorities embedded into the programs. Those independent technical authorities, you know, they don't get their assessment from their manager is not—does not come from the program. It's completely independent, and if they need to throw a red flag and say this isn't safe, they have a job to do that. And we want those independent technical authorities for safety to stay in place whether it's engineering or technology or, you know, human factors, medicine, all of those safety valves are in place, and they're strong, and we're going to keep them. We're not going to take any undue risk.

But I would like to say with the—when John F. Kennedy announced we were going to the moon in Congress as a matter of fact in 1961, it was only weeks after Alan Shepard passed the Karman line. It was basically a very short hop straight up and straight down. And in a matter of weeks he was announcing we're going to go to the moon by the end of the decade.

That was a moment in American history that was transformative. It captured the imagination of the American people. It wasn't without challenges, but we achieved it, and now it's an accomplishment that everybody still quotes, everybody still talks about. My children watch the videos, and I'm sure your family has as well.

Mr. MCADAMS. Yes.

Mr. BRIDENSTINE. So all of these things I think are important. Like this is—in my view, this is a great opportunity for this agency, it's a great opportunity for the country, and I think we can capitalize on it.

Mr. MCADAMS. Thank you, Mr. Administrator. I applaud the ambition. Let's make sure we do it safely.

Mr. BRIDENSTINE. Yes, sir.

Mr. MCADAMS. And I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Olson.

Mr. OLSON. I thank the Chair and welcome to a former Member of this Committee, a former naval aviator, and a fellow Rice University graduate.

Mr. BRIDENSTINE. Go Owls.

Mr. OLSON. Go Owls.

Mr. BRIDENSTINE. Hoot.

Mr. OLSON. Before I ask you questions, I'm compelled to make some comments on Vice President Pence's vision of going to the moon in 5 years. We all know NASA's attitude from Apollo 13. Failure is not an option. But listening to my colleagues from the other side of the aisle, that phrase may now be failure is the only option.

I remind my colleagues the young President John Fitzgerald Kennedy told the American people at our alma mater Rice University—and this is a quote—"I realize that this is in some measure an act of faith and vision," end quote. "We choose to go to the moon in this decade." He said that on September 12, 1962. Neil Armstrong said, "That's one small step for man, a giant leap for mankind" 6 years and 311 days after that inspiring speech.

We can go back to the moon if we make the commitment in 5 years. And I think to go to Mars we have to go back to the moon first. The moon should be the place we train for going to Mars. A few examples, the moon's gravity is one-sixth of our gravity. Mars is one-third. You talk to Neil Armstrong—I did—before he passed on or Buzz Aldrin. They tried to walk on the moon. Within minutes, they learned how to hop to get around. My point is we have a great pool by the Johnson Space Center—they can train there—but it's not actually working in the atmosphere—the gravity we have between Mars and the moon.

We have one difference, too, about going to the moon in the 1960s today is, we have the rocket being built right now, the SLS. It's going forward. It's online. It may be ready to fly in the next couple years. The Saturn V came out of nowhere to go flying. We're way ahead of the curve on that one. We have the crew vehicle. This Committee saved the Orion capsule when it was killed with the previous Administration's destruction of the Constellation Project. We saved that capsule to take human beings, Americans back to the moon, to Mars, and beyond.

It's been mentioned, too, we have to have bigger rockets to go to Mars, faster rockets. Right now, the moon is about 2 days away with the current rockets. Jim can tell you Mars is probably 3 months, 4 months, 6 months?

Mr. BRIDENSTINE. Seven maybe.

Mr. OLSON. Seven months.

Mr. BRIDENSTINE. Yes.

Mr. OLSON. That means people have to have food, they have to have water, supplies. That's going to be one big heavy rocket, have to have new propulsion system. For example, a former astronaut named Franklin Chang-Diaz had a rocket that keeps accelerating.

Jim, I've forgotten what the rocket is called, but it goes faster and faster, not the speed of sound but the speed of light, maybe get to Mars within 3 weeks as opposed to 3 months.

Also, there's a big belt of radiation between Earth and Mars. We've never been through that with humans. We have to learn how we get through that band and keep humans alive.

So my question to you my good colleague, Administrator Bridenstine, do you think going to the moon helps us get to Mars?

Mr. BRIDENSTINE. Without question. In fact, I would argue you cannot get to Mars unless you use the moon as a tool to get there. And what I'm talking about is we need to learn to live and work on another world. You don't want to try that for the first time when it's going to take 7 months get home and, by the way, you've got to be there for 2 years before you try to come home because the Earth and the moon are not going to be on the same side of the sun. So the moon is the proving ground. We have to learn to live and work on another world.

We've proven—going back to Apollo 13, we have proven that you can come home safely when something goes wrong during a moon mission. If we were to do that on the way to Mars, it would be devastating.

Mr. OLSON. The Franklin Chang-Diaz rocket is called the plasma rocket. Basically, it goes faster and faster and faster.

One question about China.

Mr. BRIDENSTINE. Yes.

Mr. OLSON. As you know, Apollo 11 left a plaque on the moon that said, "We came in peace for all mankind." I guarantee you if China put a plaque on the moon it'll say something like "We came to make the moon ours." Look no further than right here on Earth, the South China Sea. China has torn apart pristine reefs, six of them, to make bases out of them. Do we think they'll change their attitude going to the moon as opposed to what they're doing here on Earth or should we ramp this up and go to the moon ASAP?

Mr. BRIDENSTINE. You're asking me?

Mr. OLSON. I'm asking you, yes, sir.

Mr. BRIDENSTINE. Oh, I think we should go ASAP. But it's also true, just as you identified, when you talk about a plasma rocket, the idea is when you think about a rocket, you've got two things. You've got mass that comes out of the back end of the rocket and you've got how fast that mass is going. What Franklin Chang-Diaz is doing is he's accelerating subatomic particles, electrons, as you mentioned, at, you know, close to the speed of light. And so when you talk about the mass being that small, that means the acceleration has to be that fast, which is why that would be a capability—that would be—I know earlier Congressman Foster was talking about nuclear capabilities. That would be nuclear electric propulsion, which would be an absolute game-changer. Getting to Mars in a matter of weeks rather than a matter of months would be transformational and enable us to do more, and it would protect human lives. So we are making investments in that. In fact, those investments are in this budget and would be 100 percent transformational.

Mr. OLSON. I think I'll close my time by saying go Navy, beat Army.

Mr. BRIDENSTINE. Go Navy.

Chairwoman JOHNSON. Thank you very much. Mr. Casten.

Mr. CASTEN. Thank you, Chairwoman Johnson. Thank you, Administrator Bridenstine.

In 2009, the National Academies published the study "America's Future in Space," aligning the civil space program with national needs. And, among other things, and said, quote, "NASA and NOAA should lead the formation of an international satellite observing architecture capable of monitoring global climate change and its consequences." Congresswoman Bonamici also brought up the 2018 Earth Science Decadal Survey which prioritized the measurements that would be taken from two missions, the PACE mission that she mentioned and the CLARREO Pathfinder mission. Both of those missions I think are widely regarded as crucial in helping us measure how our climate is changing and to plan mitigation and adaptation policies.

You know, we've already mentioned that that's been curtailed in the President's budget. I think it's worth reminding that those were cut in the last two budgets from the Administration. Those programs exist today not because of the Administration but because Congress insisted on keeping those programs going.

Mr. BRIDENSTINE. And we are, sir, keeping those programs going, and we're moving rapidly to get those programs online.

Mr. CASTEN. Well, but as you've mentioned, they're being curtailed now because of the changes that you're putting in place, and so you had mentioned that there was a budgetary pressure to terminate those missions in your earlier comments. Was there any scientific basis for terminating those missions?

Mr. BRIDENSTINE. There indeed was. CLARREO Pathfinder is a technology demonstrator to be on the International Space Station. It ultimately is basically a radiation budget instrument that, you know, we have other instruments in orbit right now that are measuring the radiation budget of the Earth. In other words, energy comes in from the sun. It's in optical parts of the electromagnetic spectrum and other parts of the electromagnetic spectrum, and then when that energy dissipates, it's an infrared. And so we're measuring the total basically radiation budget of the Earth so that we can monitor climate change. And we're doing that not just with CLARREO Pathfinder, which is simply a technology demonstrator. We're doing it with missions that are already on orbit.

Mr. CASTEN. Well, if I could ask you, please, to submit to the Committee a specific list of those missions that are going to provide the information that we're losing——

Mr. BRIDENSTINE. Absolutely.

Mr. CASTEN [continuing]. In that. And I guess I'd also like to know—you mentioned that you had some consensus from the scientific community. Can you provide specifically who in the scientific community has confirmed that cutting those missions will not interfere with our ability to understand how our climate is changing, what we need to do to adapt?

Mr. BRIDENSTINE. I can provide you with that.

Mr. CASTEN. OK. Well, it seems to me that the budget that you're proposing has a sense that exploration should be the primary mission of NASA rather than understanding the one planet

in the universe that we know actually has the capability to accommodate human life. There is cutting in this program for outyear programs. We've got funding right now for studying the Earth but cutting an outyear programs, and under these scenarios if I'm following the math, NASA is not going to be initiating any new high-priority decadal missions over the 5-year budget horizon, which leaves the possibility for a gap with really no priority strategic missions underway and would cut Earth science in FY2020.

Given all that—and this is just a yes or no question—do you personally believe that anthropogenic global warming is real and happening?

Mr. BRIDENSTINE. Absolutely I do. As a matter of fact, carbon dioxide is a greenhouse gas. We've put more of it into the atmosphere than ever before, and it is in fact causing climate—the climate to change. And, by the way, we're studying every day—in fact, we're launching here in a month the Orbiting Carbon Observatory 3, which was cut in the last budget request but not in this budget request.

Mr. CASTEN. So do you believe that we currently have the tools to meet the recommendation of the National Academies that NASA and NOAA should lead the formation of an international satellite observing architecture capable of monitoring global climate change and its consequences?

Mr. BRIDENSTINE. I absolutely do. Just to be clear, Congressman, this budget request is higher than five of the budgets under President Obama for Earth science specifically.

Mr. CASTEN. But we're cutting the programs that I think are—we'll find out when we see your submission coming back. What do you think are the chances—you know, I have a real fear that we may have a century left that this planet is truly habitable, particularly on our coastlines and runaway temperatures and melting permafrost. What do you think are the chances if we run into a situation in the next century where this planet is not as habitable as we'd like it to be that we have the ability to escape Earth and live on another planet?

Mr. BRIDENSTINE. Well, that—that's a—I don't—I don't really have any way of answering that question.

Mr. CASTEN. Would you say it's greater than 1 percent?

Mr. BRIDENSTINE. Within how many years?

Mr. CASTEN. Within a century. Would you say it's greater than 1 percent?

Mr. BRIDENSTINE. You're talking about moving humanity off Earth to another planet? I—I don't—I'm not banking on that.

Mr. CASTEN. So then how do you justify overprioritizing exploration at the expense of understanding the planet we have?

Mr. BRIDENSTINE. So I think what exploration does is it inspires the Nation. We go back to the Apollo era and we look at everything that came from the Apollo era. I hear about Tang and I hear about Velcro, but what we're talking about is communication architecture, so the way we—many people probably listening right now watch DIRECTV or Dish Network, maybe they listen to XM Radio, maybe they get their internet broadband—as many of my former constituents from Oklahoma, they get their internet from space.

Like all of those communication architectures were born from an idea that we should go to the moon back in the 1960s——

Mr. CASTEN. I think I'm out of time, but I'm all for inspiration and future generations. I just want to make sure that we have future generations. Thank you.

Mr. BRIDENSTINE. Yes, sir.

Chairwoman JOHNSON. Thank you very much. Mr. Baird.

Mr. BAIRD. Thank you, Madam Chair. And, Mr. Bridenstine, we appreciate you being here.

You know, space exploration is certainly exciting in its own right, and then finding the tons of frozen water on the moon certainly adds to its intrigue as far as a steppingstone to going to Mars. And I think it's interesting that frozen water cannot only furnish water but it can furnish fuel and hydrogen and oxygen and so on and so forth, very interesting.

Purdue University is in my district, and, as you know, we've produced 24 astronauts. Among those is Neil Armstrong, Gus Grissom, Loren Shriver. Purdue has a long history in space and aeronautics innovation. The National Defense Industrial Association is hosting a conference at Purdue University over the summer on the topic of hypersonics.

So in that vein can you give us any more detail about NASA's plan to invest in the hypersonic technology?

Mr. BRIDENSTINE. Absolutely. So this is a part of our portfolio, and it's an important part. We talk about, you know, what we do as an agency. We have to get through the atmosphere in order to go to space. Hypersonics are a piece of that. And in fact we have a lot of the facilities and the capabilities that are resident within NASA that other agencies use for those capabilities as well, for testing and ultimately developing hypersonics, so we are a partner with other agencies at the same time. It's an important part of what we do.

Mr. BAIRD. Thank you. Can you also describe to the Committee how NASA's partnership with universities like Purdue on cutting-edge research—and it may impact agriculture, and I have a tremendous interest in that as well.

Mr. BRIDENSTINE. That's—yes. So——

Mr. BAIRD. And——

Mr. BRIDENSTINE. Go ahead.

Mr. BAIRD. No, no, I was just going to ask how this Committee could be helpful in helping those partnerships grow so——

Mr. BRIDENSTINE. Great question. No. 1, universities help us reach more of the country with the goodness that NASA delivers. I would say just so you're aware Purdue, the Center Director at the Johnson Space Center in Houston is a Purdue graduate. The Associate Administrator of the Human Exploration and Operations Mission Directorate here in Washington, D.C., is a Purdue graduate. There is a—and forget about the 24 astronauts; they're littered throughout all of NASA, so you should be proud of this university that's in your district.

Going back to the ag piece—and I think this goes to Representative Casten's question as well about what NASA does and why Earth science is so important. Climate change is a big piece of what we do. We're the only agency that does it, and we do more

of it than any other nation in the world by far, and it's a good thing.

What we're learning now is from the Earth science capabilities that have been delivered for purposes that weren't focused on agriculture, we're actually now applying that capability to do a number of things, including increasing crop yields while reducing water usage. We've got a partnership with—going back to the university question you asked, sir, partnership with the University of California Cooperative Extension, and what they're demonstrating is that with our remote sensing from space of the agriculture communities in California we are increasing crop yields while reducing water usage by 25 percent, which means that water is now available for rivers and reservoirs in other areas. We're potentially in fact saving species that are at risk, and at the same time we're feeding more of the community than we otherwise would have fed.

So crop yields are going up 25 percent, water usage is down about 25 percent, and at the same time we're preserving the nitrates in the soil. So normally, when you overwater, those nitrates erode away. And there's two problems there. No. 1, the plants don't have them, which is why the crop yields aren't as high; and, No. 2, it ends up in the water that humans drink, which costs millions and millions of dollars to clean. So the goodness that is coming from the Earth science budget of NASA has a lot of application.

Now, we're just scraping the surface with these cooperative extensions—with this cooperative extension of the University of California. The goal is to expand this in fact nationwide and then worldwide. In 2017, NASA was able to predict a severe drought in Uganda in 2017, and because of that, we were able to mitigate a disaster with millions of dollars of the American taxpayer dollar, but it prevented the natural disaster that would have cost dozens of millions of dollars. So we not only save lives, we saved American taxpayer dollars because of this capability that we have resident in the Earth Science Division of the Science Mission Directorate.

Mr. BAIRD. Thank you very much. I'm very glad to hear that. I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Beyer. Mr. Cohen.

Mr. COHEN. Thank you, Madam Chair, and I'd just like to ask a couple of questions. First, I was all concerned when we decided to use Russia for all of our launches many years ago. Apparently, that's worked. We haven't lost anybody yet, although there was one——

Mr. BRIDENSTINE. Yes, sir.

Mr. COHEN [continuing]. That didn't do too well. When are we going to have our own flights? And when we do, what will the Russian program be? Will we have it as a secondary option or what?

Mr. BRIDENSTINE. Great question, and it's something we need to start really communicating. I think it's an important issue. Yes, this year we believe we're going to have two commercial crew providers that enable us to launch our astronauts from American soil to the International Space Station. The goal here though is not to replace our partnership with Russia. The International Space Station has proven to be an amazing capability, a channel of communication with a country that, as you're aware, we have all kinds of

terrestrial disputes but, you know, since the 1990s we've been able to collaborate on the International Space Station and even before that if you go back to the Shuttle-Mir program and even before that if you go back to Apollo–Soyuz, height of the cold war, we have, as a Nation, been able to cooperate in space.

They have amazing capabilities. We can take advantage of that. We have amazing capabilities that they can take advantage of for science and exploration and discovery. We want to make sure that when we do have our own capability that they can launch on our rockets and we can launch on their rockets. So the partnership continues. It's just more of a partnership rather than us purchasing seats from them as a customer. It would be more of a partnership, in other words, a no-exchange-of-funds kind of bilateral partnership for access to low-Earth orbit.

Mr. COHEN. So once we get our rockets going and get us to the moon, we will not be using the Russians so much?

Mr. BRIDENSTINE. It'll be a partnership. It'll be a partnership rather than a dependency.

Mr. COHEN. And you feel confident that—I don't think they've lost anybody in space yet, have they?

Mr. BRIDENSTINE. Not since we've been dependent on them for our access to the International Space Station. We had one rocket that we launched back in October——

Mr. COHEN. Yes.

Mr. BRIDENSTINE [continuing]. But because of the—their design, they were able to eject their crew module and everybody came home safely.

Mr. COHEN. Going to moon and going to Mars, is that what every other country has as their line, first moon and then to Mars?

Mr. BRIDENSTINE. Well, I will tell you we're unique in that we have the capability to deliver this opportunity. I will tell you that every country in—the head of every agency that I've met with is very excited about going to the moon, and they're looking forward to partnering with us. This is about—this is really American leadership at its finest. There is just a lot of excitement all around the world to partner with us on this.

Mr. COHEN. What has China done? Did they go around once? Did they send some——

Mr. BRIDENSTINE. They have had a number of landers on the surface of the moon. They currently have Chang'e 4 on the far side of the moon.

Mr. COHEN. But no people?

Mr. BRIDENSTINE. They've never had a person on the moon.

Mr. COHEN. All right. But China wants to do that obviously.

Mr. BRIDENSTINE. They do.

Mr. COHEN. And then after that is there a plan to go to Mars or do they have a plan beyond that?

Mr. BRIDENSTINE. I don't know that they have a plan to go to Mars at this point.

Mr. COHEN. OK. You were talking about supersonic flight——

Mr. BRIDENSTINE. Yes, sir.

Mr. COHEN [continuing]. And a quick research, Boom and Boeing are both kind of looking into this as private—what's NASA's role in this?

Mr. BRIDENSTINE. That's a great question. So what we do is we prove capability, we prove technology, we retire risk, and our goal is always to commercialize, to license, to give other people the capability of advancing their technologies or using our technologies to their benefit, the intent being that it enables the United States of America to remain a leader in this very high technological field of aerospace and then increase exports. That's the role that we play. We do not want to compete with private sector. We partner with the private sector so that they can actually achieve more in the international community.

Mr. COHEN. And is the Concorde coming back?

Mr. BRIDENSTINE. Well, the Low Boom Flight Demonstrator is not the Concorde, but it will—the Concorde—it created a very loud boom——

Mr. COHEN. Yes.

Mr. BRIDENSTINE [continuing]. And that's why it couldn't fly over the United States. It only flew over the ocean. What we're trying to do is something entirely different where we could have a supersonic aircraft fly over the United States and the boom would be insignificant.

Mr. COHEN. I thought I read somewhere that Concorde, British, French, they were going to start to do flights again over the ocean.

Mr. BRIDENSTINE. I don't know about the Concorde. I do know that there's a lot of companies that are interested all over the world interested in supersonic flight again.

Mr. COHEN. And then let me ask you about the spacesuits that were not——

Mr. BRIDENSTINE. Yes, sir.

Mr. COHEN [continuing]. For women. You had one that could fit a woman; you didn't have two. I know it's Saturday Night Live and all, but still——

Mr. BRIDENSTINE. So——

Mr. COHEN. You'd have suits for dogs and monkeys and another woman?

Mr. BRIDENSTINE. So we did have two spacesuits for two women, and the challenge is each spacesuit is not—think of it as a spacecraft. That's what it is. It's a spacecraft that goes outside the International Space Station and they're designed not just for the person but for the specific mission. And our astronaut Anne McClain made a determination that in the interest of crew success that she thought it would be better to change the spacewalk person rather than to change—modify the spacesuit. We—as NASA, we had an option to modify the spacesuit. We made a—I say we. She made the call that it was better to not modify it, which would take hours and inject risk. She made a determination that it would better to change the crew rather than the suit.

And just so you know, sir, we are making sure that in the future both genders are going to be accommodated 100 percent.

Mr. COHEN. And let me close just by saying I've been very impressed with your presentation and feel comfortable about your being at NASA, and thank you for doing this. And I think we do need to get as quickly as we can I guess to the moon and et cetera, but just keep in your mind the whole time you're being told to speed it up—the O-rings.

Mr. BRIDENSTINE. Yes, sir.

Mr. COHEN. You know, I think there was quite a bit of suspicion that the politics said get that flying regardless and the O-rings, so——

Mr. BRIDENSTINE. Absolutely.

Mr. COHEN [continuing]. Thank you.

Chairwoman JOHNSON. Thank you very much. Mr. Weber.

Mr. WEBER. Thank you, Madam. Jim, welcome back.

Mr. BRIDENSTINE. Thank you, great to be here.

Mr. WEBER. Glad to see you here.

Mr. BRIDENSTINE. Always.

Mr. WEBER. You went to Rice University, and of course——

Mr. BRIDENSTINE. Can you imagine?

Mr. WEBER. I know. Well, we'll welcome you back to Texas to spend lots of money any time. Of course that's where our great President JFK made his pronouncement, "We choose to go to the moon not because it's easy but because it's hard."

And refresh my memory, Jim, if you don't mind me calling you that, how long did it take us to get to the moon at that point?

Mr. BRIDENSTINE. Let's see. He made the announcement in Congress in 1961. He made the announcement at Rice University in 1962, and we had boots on the moon on July 20, 1969.

Mr. WEBER. And I know there was people back then, to use that phrase, hot air that a lot of people thought that was hot air, but in reality we actually got that job done. It was 7 years give or take, right, and would you characterize that—I know you're a little bit of a student of history. That was before your time. You were born in 1975?

Mr. BRIDENSTINE. I was born—yes, I'm the first NASA Administrator that was not alive when we had people on the moon.

Mr. WEBER. Well, you're doing a fine job.

Mr. BRIDENSTINE. Thank you.

Mr. WEBER. So that was 7 years. Would you characterize that as uncharted territory?

Mr. BRIDENSTINE. A little bit.

Mr. WEBER. A little bit, absolutely. Is it fair to say that we had less computing power back then than we currently have?

Mr. BRIDENSTINE. Slightly.

Mr. WEBER. A little bit? Did we have less funding back then than we have now?

Mr. BRIDENSTINE. Actually, no, we had a lot more funding.

Mr. WEBER. Is that right? So percentagewise we were good on funding?

Mr. BRIDENSTINE. In 2014 dollars at our peak it was——

Mr. WEBER. Right.

Mr. BRIDENSTINE [continuing]. It was about $40 billion annually was NASA's budget. And so today it would be, you know, about $20 billion.

Mr. WEBER. So you could say that that was a sign of what a priority it was for us.

Mr. BRIDENSTINE. It was a high priority.

Mr. WEBER. Absolutely it was high priority. Did we have less technology back then than we have today?

Mr. BRIDENSTINE. A lot less.

Mr. WEBER. A lot less. So some would say did we have less belief and faith that we could do it back then?

Mr. BRIDENSTINE. I guess you could make that argument.

Mr. WEBER. I know you weren't on the Earth here at that point, but I can tell you there was a lot of people thought we'd never get it done.

In your being a student of history and being so involved in NASA, and I so appreciate you, on behalf of the 17,000 employees, by the way, thank you for being here and what you're doing. Have you seen any other President announce four national space objectives?

Mr. BRIDENSTINE. Not in this way, not anywhere near this level of commitment with these really very impressive goals.

Mr. WEBER. Right, absolutely. So based on what we were just talking about, you know, less technology, less computing power, and a lot of people didn't know if we'd be able to make it, you have confidence that we can hit that 5 years?

Mr. BRIDENSTINE. I believe it can be done.

Mr. WEBER. Yes, I would agree with you and say that what we have right now in NASA, what a fine organization, if it is our priority, if we double down and get it done, we're going to get 'er done. And I would argue that most of us on the Science Committee believe we are going to get it done too, so I thank you for that confidence.

I want to say a couple things about it. There are a lot of good things that come out of NASA, and the discussion between you and Congresswoman Horn, you talked about a realm of possibility. I love that phrase. There's so many things that are within our realm of possibility, and NASA is leading the way on that. Don't you agree?

Mr. BRIDENSTINE. Agree completely.

Mr. WEBER. And I was listening to you all talk and I was also listening to you talk about the reduction gear that had been developed by NASA for airplanes where it's flat on the bottom so that when they land—explain that again.

Mr. BRIDENSTINE. Well, I was just looking at the nacelles of an engine not too long ago, and I noticed that it flattens out at the bottom. But the reason it was flattening out is because then the nacelles keep getting bigger and bigger——

Mr. WEBER. Yes.

Mr. BRIDENSTINE [continuing]. And the question is I didn't know why, but I learned that it's because of technology that NASA developed that—in conjunction with our commercial partners to improve the fuel efficiency and the environmental, you know, I guess mitigation efforts of our industry so that we can improve exports for the United States of America.

Mr. WEBER. Absolutely. I was glad to hear your exchange about the climate change thing. America ought to be in the leadership, we ought to be developing that technology, and NASA can lead the way——

Mr. BRIDENSTINE. And we have, yes.

Mr. WEBER [continuing]. On it. You bet you. Glad to hear that. And I'll just say this. We're looking at one space directive of four right now——

Mr. BRIDENSTINE. Yes.

Mr. WEBER [continuing]. Just one.

Mr. BRIDENSTINE. That's right.

Mr. WEBER. And I will say that it's visionary and, Madam Chair, if I can be so bold as to say you love hearing about STEM. This is going to help our STEM program because it is visionary. I will say it's invigorating. Ma'am?

Chairwoman JOHNSON. We need STEM to get there.

Mr. WEBER. We do need STEM to get there. Thank you for pointing that out. It's invigorating. You're going to see Americans get behind this I believe much as they did in 1961 and 1962. I hope we're going to see bipartisanship out of this. I think we're going to see America get behind it, youth and STEM as the Chairwoman so appropriately pointed out.

Look, I would argue that this is about American exceptionalism, Administrator Bridenstine. You made the comment that America needs to lead the way, and I will say that's exactly what's going to happen. It's going to be American exceptionalism, it's going to help STEM, it's going to help inspire and especially in the STEM—back to STEM—and I can go any much further because I'm out of time. Do you see any reason why we shouldn't go forward with this?

Mr. BRIDENSTINE. I think we absolutely need to.

Mr. WEBER. I think you're on track, Jim. Thanks a lot.

Mr. BRIDENSTINE. Thank you.

Chairwoman JOHNSON. Thank you very much. Mr. Beyer.

Mr. BEYER. Madam Chair, thank you very much. And, Administrator, welcome.

Mr. BRIDENSTINE. Thank you.

Mr. BEYER. You know, like many of my colleagues, I was disappointed to see that the President's budget request for 2020 has many of the same cuts to NASA science, education, Earth science programs that it did last year even after Congress, you know, basically stood many of them up. Eliminating NASA's key STEM programs, PACE, CLARREO, they seem shortsighted and we need to continue investing in both our generation and climate research. But the appropriations process will work a lot of that out I know.

I am very excited about off to the moon and off to Mars. This is really exciting stuff, but the tradeoff that I'm really concerned with is eliminating the highest-ranked priority of the decadal survey, which is WFIRST, you know, the Wide Field Infrared Survey Telescope.

When Commissioner Bolden was here a couple of years ago—I think you were sitting on the Committee at the time—I asked him NASA's constancy of purpose, what should it be? Without hesitation, he said science. And the most fundamental and essential science we have right now is trying to figure out about dark energy, about what's happening in the origin of the universe with the infrared stuff, exoplanets, and I think initially—James Webb—that you're very committed to and WFIRST were planned together. They complement each other. So why does it make any sense to take WFIRST out of our budget? And isn't this going to jeopardize that project in the long run and diminish what we can get from James Webb?

Mr. BRIDENSTINE. It's a wonderful question, Congressman, and the way I would answer it is the James Webb Space Telescope is really our biggest flagship mission in the Astrophysics Division of the Science Mission Directorate, and we are committed to it. We have to be committed to it. By the time this is over, March 2021 we're going to launch it, it's—we're going to be $9 billion into that program.

The challenge is—and this goes back to an earlier question about maintaining schedule and maintaining cost. When I first came in, that program was being pushed back and the cost was increasing. I had to come back to this Committee to get authorization to in fact go forward with this mission given the cost increase and the schedule delay.

All of that being said, when we have a flagship mission like that that goes well beyond what we ever envisioned, it ends up impacting other missions within the Astrophysics Division. So I think, as we go forward, what we have to consider and what I'm hoping to work with you on is a balanced portfolio. We certainly want to do flagship missions, but when we have a flagship mission like this that goes over and then we're on the brink of starting another flagship mission, the only way to do that would be to cannibalize a lot of smaller-class missions, medium-class missions, and when we do that activity, then we put a lot more risk on the entire Astrophysics Division. So we have to get smarter I think in the future of creating a more balanced portfolio.

And you're absolutely right; the WFIRST is to work with James Webb. It's important that we get James Webb, you know, into space because ultimately, to the extent that we ever have WFIRST available to us, it needs to work in conjunction with James Webb. If James Webb doesn't launch, then WFIRST is not going to be as useful, although it would be tremendously valuable.

Mr. BEYER. Well, please count on us to continue to press on WFIRST in the years to come——

Mr. BRIDENSTINE. Thank you.

Mr. BEYER [continuing]. From the Science Committee.

Mr. BRIDENSTINE. You bet.

Mr. BEYER. I'm sure you've seen the charts that show the percentage of our Federal budget or percentage of GDP that the NASA budget was back when we were going to the moon——

Mr. BRIDENSTINE. Yes.

Mr. BEYER [continuing]. And now we're going to go again into Mars. You talked about the $40 billion in today's numbers, 2014.

Mr. BRIDENSTINE. Yes.

Mr. BEYER. Realistically, how do you expect to be able to do this when our NASA budget is a fraction of what it was before?

Mr. BRIDENSTINE. It's a great question. To start, we're making assessments right now as to—if we're going to land in 2024, which we're going to do, the question is how do we achieve that? And we're going to be coming back with a budget amendment.

No. 2, it's also true that we have more capabilities right now, and I think Congressman Weber hit on a lot of these. We have the miniaturization of electronics, we have reusable launch vehicles, we have commercial launch vehicles, we have a lot of the hardware that exists right now that didn't exist in 1961 and in 1962 when

President Kennedy made his famous speeches. All of those capabilities collude to say that we have an opportunity here, should we choose to accept it to, no kidding, get to the moon in 2024. That, you know, kind of vision is in front of us if we want to go after it, and I think we can achieve it given what is available right now. And don't get me wrong; it's not going to be without additional resources. But the key in order to get that of course is bipartisan consensus, and I understand that and I'm working toward that.

Mr. BEYER. Great. Thank you very much.

Mr. BRIDENSTINE. You bet.

Mr. BEYER. Madam Chair, I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Babin.

Mr. BABIN. Yes, ma'am, thank you very much, Madam Chair.

Good to see you there, Mr. Administrator.

Mr. BRIDENSTINE. Good to see you.

Mr. BABIN. I appreciate all the great work you're doing.

I proudly represent the Johnson Space Center in Houston, which manages the International Space Station, the Lunar Gateway program, and development of the next-generation spacesuits. And I understand that NASA is currently undergoing a study to evaluate the cost of returning to the moon, as we've been speaking about this morning. JSC stands ready to execute the Vice President's very exciting vision to return to the moon as soon as possible.

So I wanted to ask you just a few questions. How much will it cost to complete the Lunar Gateway as proposed in the FY2020 budget request?

Mr. BRIDENSTINE. So there's a number of issues. When we go to the moon in 2024, in order to achieve that, we have to accelerate the Gateway process. We need a power and propulsion element, and we need a habitation module. We need to be able to stage—forward stage if you will landing capabilities so when we launch humans in 2024 they have the tools necessary to get to the surface of the moon. So all of those right now are in flux, and it's important for me in the coming weeks to come back to you with what that cost is going to look like.

Mr. BABIN. OK. I got you. What impact will accelerating exploration of the moon have on the International Space Station?

Mr. BRIDENSTINE. It shouldn't have any impact on the International Space Station. Low-Earth orbit is still key to our mission, and it should have no impact.

Mr. BABIN. OK, great. How much will it cost to accelerate lunar lander development? I guess you'll have to get back with us on that as well?

Mr. BRIDENSTINE. Yes, sir, I'd appreciate that.

Mr. BABIN. OK. Our current spacesuits were developed in the late 1970s. Recent EVA (extravehicular activity) issues have highlighted NASA challenges with spacesuits. After losing suits in the Challenger, Columbia, and SpaceX cargo accidents, we only have a handful left in inventory. Over the last several years astronauts have even almost drowned in their spacesuits. The current spacesuits used on ISS are not capable of surface operations. NASA issued a report to Congress that laid out a plan for future spacesuit development. Will that plan be accelerated now that we are accelerating exploration of the moon's surface?

Mr. BRIDENSTINE. Sir, in order to get to the moon surface, we have to have new spacesuits.

Mr. BABIN. OK.

Mr. BRIDENSTINE. It's going to——

Mr. BABIN. It's a no-brainer.

Mr. BRIDENSTINE. Yes.

Mr. BABIN. Yes, OK. And what do you expect that cost to be? And will JSC maintain its role in spacesuit development?

Mr. BRIDENSTINE. The astronaut office at JSC will absolutely be involved, and their role is not going to change. Certainly the cost is something I'm going to have to get back to you on.

Mr. BABIN. OK. And, as I said earlier, the American public is excited by the Administration's enthusiasm for space exploration, and I certainly look forward to helping achieve all of these very, very exciting goals.

And then I think I've got a little time left. Last month the Chairwoman and Ranking Member sent a letter to the Commissioners of the FCC (Federal Communications Commission) expressing concern about its proposed radio frequency spectrum auction. Based on feedback from the scientific community, their letter highlighted the need for interagency consultation among affected scientific agencies and the consideration of unintended consequences on areas such as weather forecasting before the auction could move forward. Can you explain to the Committee what NASA's role is during the interagency consultation process and concerns that you have about last month's auctions?

Mr. BRIDENSTINE. A great question. So NASA works with the NTIA (National Telecommunications and Information Administration), which is the government kind of arbiter of spectrum issues, and NTIA ultimately represents us to—represents NASA to the rest of the government when it comes to, you know, spectrum auctions and that kind of thing.

I will tell you that the 24-gigahertz spectrum that is being auctioned could have an impact on NASA's missions. When we talk about sensing the Earth in the 23-gigahertz range, what that enables us to do is characterize water vapor in the atmosphere. It enables us to characterize energy in the atmosphere. And why is that important? Because that's how we're able to make predictions.

I say we; NASA is not responsible for the operational capabilities, but we are responsible for developing the satellites for NOAA that operates them operationally, and that part of the electromagnetic spectrum is necessary to make predictions as to where a hurricane is going to make landfall. So that has a big impact. If you can't make that prediction accurately, then you end up not evacuating the right people and/or you evacuate people that don't need to evacuate, which is a problem. And all those have impact.

When it comes to Hurricane Sandy, for example, the United States of America believed it was going to be heading out to sea. The European model got it right. Well, it wasn't the European model; it was the European data. They had better data than we had from their systems. We want to make sure we get this right because it——

Mr. BABIN. Exactly.

Mr. BRIDENSTINE [continuing]. It's necessary life and property. It's also important to recognize when it comes to weather forecasting in general—again, you'd have to ask NOAA, but my consultations with them, we're talking about going back to 1978 levels of data. In other words, instead of a 7-day weather forecast, a 2- or 3-day weather forecast. Again, I'm not saying that they sold our spectrum. That didn't happen. But there is a risk that, depending on the power and the position of the cell towers in the 5G network, it could bleed over into our spectrum, and that's the risk. And the assessments that NASA has done in conjunction with NOAA have determined that there is a very high probability that we are going to lose a lot of data.

Mr. BABIN. A lot of challenges there, Mr. Administrator. I want to thank you for your hard work and your insight and experience, and I'm looking forward to helping achieve the goals that you've laid out for us today and still at the same time be a good steward of the taxpayers' funds.

Mr. BRIDENSTINE. Yes, sir.

Mr. BABIN. I yield back.

Chairwoman JOHNSON. Thank you very much.

Mr. BABIN. Thank you. Ms. Stevens.

Ms. STEVENS. Thank you. Administrator Bridenstine, on March 27, our House Speaker, in partnership with our fabulous Chairwoman, had a reception commemorating the 50th anniversary of landing on the moon in celebration with Women's History Month. It was held here on the Capitol and included the shining stars, the women in—mathematicians of America's space program. Were you invited to that reception?

Mr. BRIDENSTINE. I'm not 100 percent sure.

Ms. STEVENS. And so I take it you did not attend?

Mr. BRIDENSTINE. I did not attend.

Ms. STEVENS. My colleague asked about the spacesuits, and I'm not sure you're aware that Christina Hammond Koch, who is originally from Michigan where I represent, was intended to go on that——

Mr. WEBER. But she does live in Galveston.

Ms. STEVENS. That's true. But Michigan was really quite excited to have Ms. Koch go on the trip, and she was not able to. Is it correct that no woman has ever been to the moon, sir?

Mr. BRIDENSTINE. That is correct.

Ms. STEVENS. And this was a part of three spacewalks that were supposed to have taken place, and I was wondering if you could extrapolate on those missions and what the intentions of those missions were. And because the 29th has since come and gone, who went on that mission and what is expected to take place.

Mr. BRIDENSTINE. So you're talking about the spacewalks——

Ms. STEVENS. Yes.

Mr. BRIDENSTINE [continuing]. On the 29th? It was Christina Koch and it was Nick Hague, and they were replacing batteries on the International Space Station.

Ms. STEVENS. And did the mission take place?

Mr. BRIDENSTINE. It did.

Ms. STEVENS. OK, the walk?

Mr. BRIDENSTINE. Yes.

Ms. STEVENS. OK. And, Administrator Bridenstine, the budget proposal that we're discussing here today provides no funding for the Office of STEM Engagement, which includes the Minority University Research and Education Program, the National Space Grant, and on. These have been kind of longstanding initiatives, so just wondering, given what I was previously asking why the Administration—what the rationale was for cutting these programs and what you intend to do to support women in STEM and minorities in STEM?

Mr. BRIDENSTINE. Great question. So we support education initiatives for young people through the mission directorates at the agency. Earlier I was talking about one that I attended not too long ago, which was a FIRST Robotics mission—or a FIRST Robotics Competition that I participated in. We support it with engineers, we support it with scientists. We encourage young people to get involved in the STEM fields. We do all of those things. We do the things—and, by the way, the programs that you identified are currently funded, and we are using those programs. They are part of the President's co-STEM Initiative for STEM education, and we're continuing to advance those very important initiatives.

It is also true that we want to direct resources where they can have the most impact for the agency and the most impact for the country, and in the budget request we made a determination that some of these other missions for that activity are better. And, in fact, if you talk to the folks that are building robots for Mars right now, they participated in FIRST Robotics, so that shows a direct return. And the folks are doing FIRST Robotics now are interested in building robots for Mars or Pluto or Ultima Thule or wherever we may be going next, Bennu, so there's a lot of different opportunities there.

Ms. STEVENS. Well, you're obviously a significant leader, and we are so grateful for your service and your leadership of NASA. I know it was not easy during the shutdown with 95 percent of your workforce either not working or working without pay.

And I'd like to invite you to exercise your leadership and join the Chairwoman and I on occasion to sit down with STEM education groups. Black Girls CODE is certainly very significant. Later today, I'm going to meet with a group called Tech Lady Mafia that has done a lot for women in the sciences. And we continue to encourage you to reconsider slashing those programs and also would like to encourage you to support women in STEM and get that first woman on the moon for us, sir. Thank you.

Mr. BRIDENSTINE. Yes, ma'am, and I will say that in the speech that the Vice President gave last week he was very clear that the next man and the first woman on the moon will both be Americans, and we look forward to that day. And I commit to you now that if you invite me to an event, I'll be happy to come.

Ms. STEVENS. Thank you.

Mr. BRIDENSTINE. You bet.

Chairwoman JOHNSON. Thank you very much. Ms. González-Colón.

Ms. GONZÁLEZ-COLÓN. Thank you, Madam Chairwoman and Ranking Member Lucas, for actually welcoming me here. I'm honored to be part of this distinguished Committee for the first time.

I think I'm the first Puerto Rican on this Committee, so I'm really excited to serve along with my colleagues in this Science, Space, and Technology Committee.

I look forward to representing a lot of the community in Puerto Rico. You may know that 42 percent of our economy runs on pharmaceutical, manufacturing, electronic devices, and the bedrock for that is actually research and scientific investigations.

On the other hand, we do have the Arecibo Observatory, which was the biggest radio telescope in the world for 50 years, second now just to China. And mainly been funded by the National Science Foundation and NASA through their program grants.

So having said that, my questions will be, first, I do notice that this budget in terms of the science area is $677 million more than the one in Fiscal Year 2017, but I do have the concern that some of the programs, specifically the research in the area for space grants are supposed to be finished. So my first question will be specifically on that regard. How do we know that that kind of program that works with more than 150 network affiliates between colleges, universities, museums, and other consortia being restructured and dedication activities and potentially canceling the National Space Grant College and Fellowship program? I do know they need to economize and I would love you to elaborate on those programs.

Mr. BRIDENSTINE. Sure. So NASA is very committed to STEM education. We are very committed to achieving, you know, better outcomes for the United States of America when it comes to producing the next-generation scientist, technologist, engineer, and mathematician. And we do that through the various mission directorates, and we've found a lot of success in doing that, and we've made a determination through the budget request that the way we can make the most impact is in that way.

And as far as Arecibo, I will say we're planning to spend about $4.5 million with Arecibo this year and ramping up by 2022 about $5 million annually with Arecibo, which is a capability that we think is important and we currently utilize.

Ms. GONZÁLEZ-COLÓN. I'm really glad to hear that. As you may be aware, there's a lot of astonishing accomplishment of that observatory for the last 50, 60 years, among them, many Pulitzer and even scientists that won the Nobel Prize for their research in that center.

My second question will be in terms of, you know, Puerto Rico was devastated by both hurricanes. Everybody knows that. Did NASA receive all the allocated funds for the recovery of all the NASA facilities in the Nation, including the tornadoes?

Mr. BRIDENSTINE. I will have to get back to you on that. I'm not 100 percent sure, but I'll—if I could take it for the record, I'll make sure I get you a correct answer.

Ms. GONZÁLEZ-COLÓN. Thank you. As you may be aware that STEM technology and research is something that I will be pushing forward, so any way that we can help out and even work to establish more opportunities for kids in college to participate in those programs, I will be more than happy to work with. Happy to say that I yield back the balance of my time.

Mr. BRIDENSTINE. Thank you, Congresswoman.

Chairwoman JOHNSON. Thank you very much. Ms. Wexton.

Ms. WEXTON. Thank you, Madam Chair, and thank you, Administrator, for joining us here today. I know a lot of my colleagues have already talked about the zeroing out of the STEM engagement in the President's proposed budget, and I know I echo those concerns. And in particular I want to talk a little bit about the Space Grant program——

Mr. BRIDENSTINE. OK.

Ms. WEXTON [continuing]. Because I represent Virginia, and in Virginia the program is able to leverage the funds that it gets from NASA to give high school students hands-on experience at Langley Research Center to work on real-life problems alongside NASA scientists. And I'm sure you're familiar with this program.

Mr. BRIDENSTINE. Yes.

Ms. WEXTON. And I'm very fortunate because I got some first-hand experience because my nephew was a participant a couple summers ago, and he's now an engineering student at Virginia Tech. And because of his experience, he's joined the Design-Build-Fly team, and they're competing nationally——

Mr. BRIDENSTINE. That's awesome.

Ms. WEXTON. So it's—you know, it really does have an impact on those students.

Mr. BRIDENSTINE. It does.

Ms. WEXTON. Now, you said in your response to Ms. Stevens' questions that you felt NASA believed that you can make just as much of an impact in other areas with other programs, is that correct?

Mr. BRIDENSTINE. So we—so as far as the universities go, we do a lot of missions with a lot of universities. And then universities actually are very good at engaging young folks in the programs that they're developing. And so we do a lot of that activity even outside the Space Grant program, but certainly I understand your point.

Ms. WEXTON. And so you're liaising mostly now with the universities and you don't have an equivalent program for highschoolers to this Space Grant program at this time?

Mr. BRIDENSTINE. Well, we—not equivalent to the Space Grant, that we do activities with high schools all the time when it relates to, like I mentioned, the robotics—the FIRST Robotics Competition is a high school competition. NASA spends about $4.5 million annually invested in that program, and we also provide scientists and engineers as mentors for the high school students. So we do these kind of activities within the mission directorates.

Ms. WEXTON. But they wouldn't necessarily be a week-long structured program at NASA Langley or something like that?

Mr. BRIDENSTINE. In some cases we have activities similar to that. The FIRST Robotics Competition is multiple days long. But it's not the Space Grant program.

Ms. WEXTON. Very good. Switching gears a little bit, we often talk about satellites in Earth science, but there are other new opportunities for the development of long-duration, high-altitude robotic aircraft that can fly into the stratosphere and accomplish a broad range of goals at a much lower cost.

Mr. BRIDENSTINE. OK.

Ms. WEXTON. And one example of that is the solar-powered Odysseus aircraft, which is developed by Aurora Flight Sciences, which happens to be a constituent business of mine.

Mr. BRIDENSTINE. OK.

Ms. WEXTON. Are you familiar with that aircraft——

Mr. BRIDENSTINE. I'm familiar with Aurora. I'm not familiar with the aircraft itself.

Ms. WEXTON. OK. Are you familiar with the solar-powered aircraft that are—that would fly up into the stratosphere——

Mr. BRIDENSTINE. Yes.

Ms. WEXTON [continuing]. And perform a bunch of functions?

Mr. BRIDENSTINE. Yes.

Ms. WEXTON. So I'm encouraged by the fact that it can serve as a platform to support a bunch of NASA's Earth science missions like monitoring sea-level rise, understanding drought conditions on crops, looking at flooding and severe storms, and they can do all that at a lower cost than many of the satellite technologies that are out there now. So can you talk about how the Science Mission Directorate plans to use these new long-duration robotic aircraft capabilities to support Earth science mission objectives?

Mr. BRIDENSTINE. So we in fact do currently operate unmanned aerial vehicles or uncrewed aerial vehicles for the purpose of science. We also use crewed vehicles within aviation. As far as that specific aircraft, I would be thrilled if you gave me a chance to specifically understand what it does and how we are either A) using it or maybe even have an ability to use it in the future.

Ms. WEXTON. Well, I can just tell you——

Mr. BRIDENSTINE. Yes.

Ms. WEXTON [continuing]. For example, it's solar-powered, so it doesn't have to come down for refueling and you can just park it up and set it to go in like a circular motion, circular pattern. And with the right telecommunications payload, for example, it could have gone a long way to helping restore telecommunications to the island of Puerto Rico——

Mr. BRIDENSTINE. Oh, sure.

Ms. WEXTON [continuing]. After the storm. So, you know, there are many different possibilities but also for Earth science so——

Mr. BRIDENSTINE. Yes, ma'am.

Ms. WEXTON [continuing]. Is NASA exploring Earth science capability with unmanned aircraft?

Mr. BRIDENSTINE. Absolutely. Well, the answer is yes. As far as specific missions, I'm not sure. I know we do all kinds of missions with crewed aircraft. As far as what we do specifically for Earth science with uncrewed aircraft I'll have to get back to you.

Ms. WEXTON. OK. Thank you very much. I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Brooks.

Mr. BROOKS. Thank you, Madam Chairman.

Mr. Bridenstine, clearly orbital debris in space is a key challenge with moon to Mars and International Space Station, a number of different space endeavors. I noticed your public quotes concerning India's testing of an anti-satellite weapon. What can NASA do to try to minimize the amount of space debris either sponsoring or advocating treaties——

Mr. BRIDENSTINE. Yes.

Mr. BROOKS [continuing]. Or is there some cleanup mechanism? But what can we do to reduce the danger——

Mr. BRIDENSTINE. Yes.

Mr. BROOKS [continuing]. To astronauts from space debris?

Mr. BRIDENSTINE. It's an important issue. NASA has a role to play under the President's Space Policy Directive-3. We developed technology, we develop capabilities that ultimately—under Space Policy Directive 3, the Commerce Department would be responsible for space situational awareness and space traffic management. NASA has a role to play in technology development and capability development.

I would also say we have a very different role to play, which is a role of—you know, we are a tool of national power. We are a tool of soft power, and I think it's important for people around the world to understand that intentionally creating orbital debris that increases the risk to astronauts is not compatible with human spaceflight. And so if NASA can play a role there encouraging people not to engage in these kind of activities, that's an area I think where we can benefit the world.

Mr. BROOKS. Was there any prior notice from India to the United States concerning their planned anti-satellite test and subsequent creation of this potentially dangerous space debris?

Mr. BRIDENSTINE. If there was, I was not aware of it.

Mr. BROOKS. Have there been any communications with India, either as military or space agency subsequent to the test?

Mr. BRIDENSTINE. I sent a letter to the Indian Space Research Organization indicating that their activities were not compatible with human spaceflight.

Mr. BROOKS. Now, we have various agreements with India where we cooperate on space endeavors, do we not?

Mr. BRIDENSTINE. We do.

Mr. BROOKS. Is there any risk to those cooperative efforts because of India's increase in the quantity of space debris?

Mr. BRIDENSTINE. Say that one more time.

Mr. BROOKS. Sure. We had these cooperative agreements.

Mr. BRIDENSTINE. Oh——

Mr. BROOKS. India has done something that we're not real happy about because it puts our space assets and astronauts at risk. Is there any potential reduction of cooperative agreements with India as a result of their increasing space debris that is dangerous to our space efforts?

Mr. BRIDENSTINE. So they cooperative engagements, no, and I'll tell you why. I think it would be—we don't want to do anything asymmetric. If they're trying to go to the moon and it's in both of our interests for them to achieve that objective, then we want to continue to partner with them on that effort. And that—is that—is that—you know, so the—we have not changed any of our cooperative agreements based on that incident.

Mr. BROOKS. Entirely different subject, where does the United States stand among nations when it comes to astronautics technology? And what policies do we need to ensure our country's status as a leader in aeronautics and aviation?

Mr. BRIDENSTINE. So what technologies do we need?

Mr. BROOKS. Where does the United States stand among nations when it comes to aeronautics technology? I'll——

Mr. BRIDENSTINE. So——

Mr. BROOKS. Sorry, I gave you two questions——

Mr. BRIDENSTINE. OK.

Mr. BROOKS [continuing]. Back to back. We'll just focus on that first one.

Mr. BRIDENSTINE. Aeronautics, we—as an agency, we're in the lead in a lot of different ways. As a country, we're in the lead in a lot of different ways. And I think the two big—actually, a number of big things. Low Boom Flight Demonstrator we want to prove that we can fly across the United States supersonically without creating a sonic crack that ultimately could be disruptive to infrastructure and people on the ground. That capability, once achieved, I think is going to be transformative for human spaceflight within—or human flight within the atmosphere.

When we talk about the X-57 program, we're talking about an all-electric aircraft capable of carrying humans and crew. If it can drive down the cost by 60 percent of fuel, then that could be transformative and enable airplanes to fly, you know, I guess productively for-profit in regions of the country right now that are underserved because the costs are too high. So driving down cost increases access to aviation capabilities. That's the X-57 program within the Aeronautics Research Mission Directorate.

And finally, I think urban air mobility and integrating unmanned aerial systems into the national airspace system is a critical capability that will be transformative and in fact it's necessary for us to be the world leader in that endeavor just for competitive reasons around the world.

Mr. BROOKS. Thank you, Jim. I appreciate your answers.

Mr. BRIDENSTINE. You bet.

Chairwoman JOHNSON. Thank you very much. Mr. Lamb.

Mr. LAMB. Welcome back, Mr. Bridenstine. I know it's been a long morning, so I won't keep it too long. But you've gotten a lot of questions about the cuts to the STEM office and from what I can tell you've suggested that someone at NASA or some group of people with the Administration has made a decision that you can more effectively reach out and encourage young people through the directorates than through the STEM office. Do I have that right?

Mr. BRIDENSTINE. That's correct.

Mr. LAMB. Who made that decision?

Mr. BRIDENSTINE. It's—we go through an entire process as an agency, and it bubbles up from the bottom, and then we get, you know, kind of all the different parts of the—all the different agencies make their cases, all the different parts of the agency make their cases, then we have to make decisions.

Mr. LAMB. Well, who made the case that the $110 million for the Office of STEM was not worth spending this year? Who made that case?

Mr. BRIDENSTINE. Ultimately, the budget request is NASA's budget request, so I will own that.

Mr. LAMB. OK. In my State of Pennsylvania there's a Pennsylvania Space Grant Consortium, and with the money that they were getting from the NASA Space Grant, they were giving $4,000 schol-

arships to students who were either juniors or seniors at any accredited Pennsylvania college or university if they were enrolled in science, technology, engineering, or math. And it was specifically encouraged that women, underrepresented minorities, and persons with disabilities apply. All three of those groups are probably people that NASA would benefit from having more of, right?

Mr. BRIDENSTINE. Yes.

Mr. LAMB. I mean, that's an issue we have across our government.

Mr. BRIDENSTINE. Absolutely.

Mr. LAMB. Wouldn't you agree?

Mr. BRIDENSTINE. Yes.

Mr. LAMB. OK. So do any of the activities in the directorates give out $4,000 scholarships to students in college?

Mr. BRIDENSTINE. Not that I know of.

Mr. LAMB. OK. So if your budget, as you've presented it, goes into effect, there won't be more students like this in my State getting the $4,000 scholarships from NASA as they currently exist, right?

Mr. BRIDENSTINE. That's correct. To—but I want to make sure, sir, you understand we will follow the law, and we are following the law. And currently those programs are the law, and we will continue doing that.

Mr. LAMB. But I'm talking about in future cases as a result of the budget you're requesting, that program would no longer exist.

Mr. BRIDENSTINE. Correct.

Mr. LAMB. OK. And you'd agree, I mean, there's a difference between giving somebody $4,000 in tuition and loaning your scientist to a FIRST Robotics Competition, right? I mean, there's a real difference in the life of the recipient between those two things?

Mr. BRIDENSTINE. There is. On the FIRST Robotics front the reality is a lot of those—they—that's not a cheap endeavor, and so NASA does provide direct financial resources out of the Science Mission Directorate to the tune of about $4.5 million for those activities. And it enables children, high-schoolers, young folks, it enables them to participate in ways that they otherwise could not participate.

Mr. LAMB. No, and I commend you for that. I've met with the FIRST teams in my district. It's an exciting program. You know, the $4.5 million pales in comparison to the 110, and then, interestingly, the 110 really pales in comparison to the $20-some billion overall NASA budget, so it seems to me a little may be penny wise and pound foolish to eliminate $100 million out of a $21 billion budget. I mean, do you think that $110 million is going to be the difference between whether we get to Mars or whether we get to the moon or not——

Mr. BRIDENSTINE. No, I——

Mr. LAMB. —$110 million?

Mr. BRIDENSTINE. I absolutely do not.

Mr. LAMB. No. So, I mean, kids are hanging on by a thread in college, especially in Pennsylvania. Pennsylvania is an expensive place to go to college. Our State colleges are financially extremely stressed. Four thousand dollars could be the difference between staying and dropping out, especially for someone who comes from

a background where their family is not wealthy, which is a lot of people, so I just really would encourage you to think this one through. And I know the request has been made. Congress is going to do what it's going to do, but this means a lot to people in my State, and in future years I hope it gets a little bit more respect and thought from this Administration.

Mr. BRIDENSTINE. I understand.

Mr. LAMB. Thank you. I yield back, Madam Chairwoman.

Chairwoman JOHNSON. Thank you very much. Mr. Sherman.

Mr. SHERMAN. OK. I know others have had a similar line of question about SLS and Orion. You said that SLS, Orion, and the ground systems are the backbone of our Nation's deep space exploration program starting at the moon and beyond.

Mr. BRIDENSTINE. Yes.

Mr. SHERMAN. My questions concern the budget, which seem to contradict your statement. After years of delay in part due to insufficient requests and continuing resolutions, SLS, Orion, and their respective ground systems have made significant strides, strides which will bring unprecedented exploration capacity to the Nation and really the rest of the world. The engines are ready, capsules are being tested, boosters are ready, pads and infrastructure near completion. There should be a roll of music there. And then the Trump Administration delivers a budget that aims to halt and slow this progress. Is there a rocket and crew capsule that exists with the same or greater capacities as SLS and Orion?

Mr. BRIDENSTINE. No, sir. That is—as you correctly said at the beginning and I still believe 100 percent that that is the backbone of our ability to get to the moon. It's the backbone of our deep space exploration capabilities. What we did in the budget request is we delayed for a period of time the exploration, upper stage specifically because we've been having challenges with the core stage. We have to get the core stage complete, and we can fly the core stage with what we call an interim cryogenic propulsion stage and an Orion crew capsule with the European Service Module, and we can take that in fact to the moon and we can take it to the moon with humans. The exploration upper stage is absolutely important for the future, but given where we are right now with SLS, we wanted to focus all the resources specifically on the core stage.

Mr. SHERMAN. But you seem also to be seeking money for a rival approach that may not yield a launcher or a lander. What alternatives to SLS and Orion are you seeking funding for?

Mr. BRIDENSTINE. So right now we did a 2-week study on commercial alternatives to the SLS, and what we found is that none of those commercial alternatives are going to help us save on cost or improve the schedule.

Mr. SHERMAN. So it was a 2-week study?

Mr. BRIDENSTINE. We did a 2-week study. We learned—I learned a number of weeks ago that the SLS was going to be delayed again, and I made a determination that we need to find an alternative approach. We looked at all of the commercial options, heavy-lift rockets. Going to the moon is extremely hard. It's a long distance, and the mass that we need to send there is a lot. And so the SLS and the Orion crew capsule are the tools by which to achieve that objective. Commercial solutions in the future could be viable. In fact,

they will probably be necessary, but at this point SLS and Orion are the best approaches to stay on schedule.

Mr. SHERMAN. So contrary to my understanding of the budget request—and I may not be reading it with as keen an eye as yours, you're full speed ahead on SLS and Orion, but the upper stage of SLS, the so-called EUS, you're going slow on only for technical and not budgetary reasons?

Mr. BRIDENSTINE. We made a determination that we needed to focus on the core stage, and until that core stage is complete, the exploration upper stage ultimately doesn't have any value because it needs that core stage to be effective.

Mr. SHERMAN. But why not go in parallel? Why do you need—I mean, you're developing capsules in parallel with rocket engines, suits in parallel with capsules. Why is focusing on the first stage causing you to halt efforts on the second stage?

Mr. BRIDENSTINE. Ultimately because, you, we have—we're making determinations based on the constraints of the budget.

Mr. SHERMAN. So how much does this slow down the process? You got to first get the first stage right, and then you'll wake up and say, oh, now we got to do the second stage.

Mr. BRIDENSTINE. It is——

Mr. SHERMAN. What delays are we talking about here?

Mr. BRIDENSTINE. So it's very possible that next year you'll see the exploration upper stage in the budget request. It's very possible given that we now have an agenda to get to the moon in 2024, in the coming days you might see that as part of the architecture to accelerate the moon mission with an amendment to the budget request.

Mr. SHERMAN. So we may see an amendment to the budget request regarding the first and second stage?

Mr. BRIDENSTINE. It is possible, yes, sir.

Mr. SHERMAN. I yield back.

Chairwoman JOHNSON. Thank you very much. I now recognize Ms. Hill.

Ms. HILL. Thank you, Madam Chair.

Mr. Bridenstine, NASA's workforce has experienced significant aging in the last 25 years. According to the Space Foundation's The Space Report in 1993, 34 percent of NASA employees were under 35 years old and 15 percent were older than 54. By 2018 these numbers have flipped at just 15 percent of NASA's workforce is under 35 years old while 35 percent are older than 54, and we're seeing this play out in my district. Do you have any concerns about the aging of the NASA workforce, and what do you plan to do about it?

Mr. BRIDENSTINE. Yes, ma'am, 100 percent. We have a bow wave of retirements that are on the horizon. We're working very hard to make sure when that happens that we have people that can fill in and take those roles at every level of leadership in the NASA organization. So in order to achieve that, we are working with universities, with missions, and other capabilities to make sure that when people graduate from college they not only have the academic capabilities but they also have hands-on experience actually developing missions for NASA. So that's one way that we're working to make sure that we're filling in for the retirements. We're also working

through internship programs and in fact middle-career kind of programs to get folks focused on maybe joining NASA.

Ms. HILL. Thank you. I guess that kind of relates to Mr. Lamb's question of how the reduction in scholarships might be impacting that.

Mr. BRIDENSTINE. Yes. Again, so we work with universities in a whole host of different ways through the mission directorates, and we intend to keep doing that. And they're a key piece of how we're going to fill this retirement wave that we see coming.

Ms. HILL. Do you have like real projections laid out in terms of how the impact is going to look, and is there a way that we can be involved in that process or informed——

Mr. BRIDENSTINE. We do. I'd be happy to get with our HR folks and sit down with you and talk about it in detail.

Ms. HILL. Thank you. And then the second question is according to the Space Foundation's The Space Report between 2011 and 2017 the average NASA salary decreased 10 percent in real terms. We also heard—I have many NASA employees in my district who told me about the impacts that the shutdown had on morale and on people seeking other outside employment, especially when we have massive aerospace industry in our district that's outside of the government. And are you concerned about losing and not attracting highly skilled scientific and technical personnel because of those decreasing salaries and competition from the private sector and instability in government pay?

Mr. BRIDENSTINE. This is a real issue for NASA, and we're dealing with it every day, especially in our—a lot of our centers are in expensive areas. Ames, for example, is a very expensive place to live out in the San Francisco Bay area. It's where a lot of talent is, so it's a good place for us to be. We can take advantage of all that talent. At the same time our employees make a government paycheck, which is not competitive with the area in which they live.

The folks that work at NASA do it because they absolutely love it, they're committed to what we do, it's unique in the world and everybody knows it and they want to be a part of it. But certainly we are working through some really significant challenges when it comes to how we compensate our workforce.

Ms. HILL. Yes, I'd be interested in working with your HR folks on that, too, and looking at different compensation mechanisms.

Mr. BRIDENSTINE. Absolutely.

Ms. HILL. And then, lastly, Vice President Pence said that if NASA can't land on the moon by 2024, we need to change the organization, not the mission. So what does the changing the organization mean to you? And do you see this as a threat to breaking apart NASA or otherwise drastically reorganizing the way that civil space is implemented in the Executive Branch?

Mr. BRIDENSTINE. No, I don't see it as that. I mean, I think—I know exactly what he's talking about. He's talking about the fact that, you know, there has been maybe a sense that since we've been—it's been a long time since we've flown humans into space. The retirement of the Space Shuttle was in 2011. The gap was not supposed to be this long. So the question is, is there complacency?

What he said was we are fighting complacency, so he wants to get us moving faster.

I think that there is a big difference—and going back to the organizational structure, there's a big difference between operations, which is what we have on the International Space Station right now, commercial resupply, commercial crew, and operations on the International Space Station. There's that part of NASA, and then there is development. The brand-new things, the big rocket to get to the moon, the Gateway, lunar landers, all of those capabilities don't yet exist and yet soon will. That's development. That's very different than operations. So what we're working on now is a plan where we would actually have a mission directorate focused on development and a mission directorate focused on operations. We don't call it the development mission directorate because development is not a mission. We call it the Moon to Mars Mission Directorate, and so we're working through right now the process by which we could have that online in short order to help us achieve a faster lunar landing.

Ms. HILL. OK. I can appreciate that since my grandfather was an engineer on the Space Shuttle and the Apollo series.

Mr. BRIDENSTINE. Oh, wow.

Ms. HILL. Thank you.

Mr. BRIDENSTINE. You bet.

Chairwoman JOHNSON. Thank you very much. And before we close the hearing, I want to thank our witness very much for your long, steadfast testimony this morning and to remind—you can now be dismissed. And I want the remaining Committee Members to understand that they—oh, I dismissed you a little too early.

Mr. BRIDENSTINE. OK.

Chairwoman JOHNSON. OK. Come right in. Mr. Waltz is recognized.

Mr. BRIDENSTINE. I almost got away.

Mr. WALTZ. You did. You did, Mr. Bridenstine. Apologies. And it's nice to actually occupy your office, so thank you for——

Mr. BRIDENSTINE. 216 Cannon?

Mr. WALTZ. 216 Cannon.

Mr. BRIDENSTINE. It's the best.

Mr. WALTZ. Thank you for keeping that warm for me. And I represent the district that starts just north of the Cape and heads up to Jacksonville with Embry-Riddle——

Mr. BRIDENSTINE. Oh, good——

Mr. WALTZ [continuing]. At the center there, and so obviously space is in our DNA, and we're just so excited and thrilled with the growth of commercial space in particular, but just also the resurgence of what's going on.

I just left Secretary Wilson and General Goldfein in the House Armed Services and talking about the future of space there from the military side.

So, Administrator, as you know, the Kennedy Space Center in Florida is the site of a world-capable, just really incredible—of launching astronauts into deep space, just an incredible capability. Can you just talk to me about the Vice President's directive——

Mr. BRIDENSTINE. Yes.

Mr. WALTZ [continuing]. To get to the moon? And apologies if you've already gone over this, but——

Mr. BRIDENSTINE. Oh, no, it's——

Mr. WALTZ [continuing]. But it's critical to I think growth in Florida and where we're going with it and particularly how you plan to do it within the timeline——

Mr. BRIDENSTINE. Right.

Mr. WALTZ [continuing]. Given your budget request and the perceived at least disconnects there.

Mr. BRIDENSTINE. Absolutely. So going back to—I think it was February 2017 the President signed Space Policy Directive 1. In that space policy directive he said we're going to go to the moon. We're going to go sustainably. In other words, this time when we go, we're actually going to stay. It doesn't mean we're going to have a permanent human presence on the surface of the moon necessarily, but what it means is we're going to have permanent access to the surface of the moon with humans but also with landers and robots and rovers. But we're going to go, we're going to go sustainably, we're going to go with commercial partners, we're going to go with international partners, and we're going to retire risk, prove capability, and then we're going to take that to Mars.

So that I think was the foundation of what the Vice President announced last week. We put together a plan to achieve that objective given the budget constraints, and we came up with a 2028 landing date on the surface of the moon. The President and the Vice President determined that they wanted to go faster than that, so they gave us an objective to meet that deadline of 2024, which of course puts—we're going to probably need different resources than we had previously anticipated, but I will tell you the agency NASA is exceptionally excited about this opportunity. I would imagine down at Kennedy where you are there's a lot of really excited folks right now and I think at the same time not just a level of excitement but people know that we can achieve it. We know that we can achieve it.

And so the goal here is to go to the moon and go quickly but also go sustainably, and so that's what we're working on right now to develop what that plan would look like. All of the elements are there from the plan that we had previously from 2028 landing. All of the elements are there. Some of those elements we need to start moving forward, which means we're going to need a different set of resources. And so in the next—in the coming weeks I'm going to talk to this Committee and others about what those resources might look like.

Mr. WALTZ. Thank you. And in the time I have remaining, the budget proposes the termination of NASA's Office of Education and zeroes out the education account, so within the Office of Education is the Aerospace Research and Career Development program that houses the National Space Grant College and Fellowship program. That's incredibly important to Embry-Riddle, along with a number of other universities that are focused on STEM but particularly with Embry-Riddle.

We educate world-class STEM talent. I think the race into space in the 21st century space race is really an icebreaker for pulling the United States back into its world leadership role in STEM.

How does the President's budget request impact the Space Grant program?

Mr. BRIDENSTINE. So the Space Grant program specifically would not be funded in the President's budget request. It is true that when we think about how we go about inspiring that next generation, we do it through STEM activities. We're looking at doing that through the mission directorates, which we have a number of programs through the various mission directorates to accomplish that end State, and so, again, prioritizing what's the biggest impact for the agency, what's the biggest impact for the country, we determined that it was best to not fund the Space Grant program. But at the end of the day right now it is funded. We are following the law, and we are committed to following the law.

Mr. WALTZ. Madam Chairman, thank you so much. I appreciate your forbearance. Thank you. Thank you, Administrator.

Mr. BRIDENSTINE. Thank you.

Chairwoman JOHNSON. Thank you very much. And, again, thanks to our witness. You've been an excellent witness. We appreciate you being here. And I think that is our last questioner, so the record will remain open for 2 weeks for additional statements from the Members and for any additional questions the Committee may ask the witness. And the witness now is excused.

Mr. BRIDENSTINE. Thank you, ma'am.

Chairwoman JOHNSON. The meeting is adjourned.

[Whereupon, at 12:44 p.m., the Committee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. James F. Bridenstine

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:
Administrator Bridenstine
Submitted by Chairwoman Johnson

Question 1:

There has been a consensus to send humans to the surface of Mars, as directed in the NASA Transition Authorization Act of 2017. The recently transmitted Mars 2033 report, "Evaluation of a Human mission to Mars by 2033," directed in Section 435 of the Act, found that "limitations imposed by the budget render unlikely a long-term human presence on the Moon in the 2030s concurrent with a 2037 mission to Mars orbit and subsequent Mars landing mission in the early 2040s." Under the FY 2020 budget request for NASA and the Administration's goals for a permanent presence on the lunar surface, in what year could we expect to land humans on Mars?

Answer 1:

Mars remains the horizon goal for NASA's human spaceflight efforts. The Agency is taking a phased approach which will land a crew (including the first woman) on the Moon in 2024, and create a sustainable lunar presence by 2028. Using the experience gained through its cislunar activities with U.S. commercial and international partners, NASA will develop plans for a crewed mission to Mars. The specifics of this planning, including technical approaches and schedules, will be reflected in future budget requests and updated editions of the National Space Exploration Campaign report (which will be revised on a biennial basis).

Question 1a:

Given the Vice President's announcement to accelerate a lunar landing with humans by 2024, in what year could we expect to land humans on Mars?

Answer 1a:

Please see response to Question #1, above.

Question 2:

Typically, when large technological projects and missions are being conceived, the project develops cost estimates, recognizing that those estimates are preliminary. Do we have a preliminary estimate of what the Lunar Gateway would cost?

Answer 2:

The Gateway program is in formulation, and the budget is based on initial cost estimates that are subject to further refinement as the program advances through the Agency life cycle review processes. With current operating plan adjustments for FY 2019 the Gateway budget is $332 million, and the amended President's Budget Request for FY 2020 would provide $500 million

for the Gateway in FY 2020. The outyear estimates for Gateway are currently notional and will be further developed through the Agency life cycle review process and reflected in future budget requests. Additionally, our international partners are proceeding toward their respective stakeholders' approval and funding processes for evaluating whether to provide elements, modules, and capabilities for the exploration of the lunar surface, possibly through augmentation of the Gateway. NASA welcomed with enthusiasm Canada's announcement on February 28, 2019, that it would participate in lunar exploration by contributing advanced robotics to the Gateway, making the Canadian Space Agency the first partner agency to officially join NASA in the lunar exploration program. The Gateway is being designed to support sustainable missions to and operations on the surface.

Question 3:

Given that the SLS and Orion are backbones of our capability to explore deep space and the Administration's extensive plans for a sustainable and permanent presence on the Moon, have you included future SLS/Orion Exploration Missions such as EM-3, EM-4, and EM-5 in this budget request? If not, why not?

Answer 3:

The President's FY 2020 Budget Request amendment includes long-lead material purchases for Artemis 3, Artemis 4, and Artemis 5. This will enable the program to meet an annual flight rate to support lunar exploration, and these missions represent United States commitment and a core piece of NASA's infrastructure for exploration. More specifically, production under Orion is planned to commence no later than 4th quarter FY 2019 in order to deliver Orion for Artemis 3 flight in 2024. Orion initiated procurement earlier in FY 2019 on a few specific parts and materials that were identified with especially long leads to preserve the Artemis 3 flight schedule. Once started, the contract plans have been validated to phase parts purchases, assembly and testing work to meet the one-flight-per-year exploration manifest starting with Artemis 3. The Space Launch System (SLS) has included content for future missions for sustainable operations on and around the Moon, which includes Artemis 3, Artemis 4, Artemis 5, and beyond. This amendment supports award of Core Stage long-lead material for Artemis 3 and includes purchases of other SLS end items to support Artemis 4 and Artemis 5. NASA is currently finalizing fiscal and resource requirements to land humans on the Moon in 2024.

Question 3a:

When do you plan to contract for EM-3, EM-4 and EM-5?

Answer 3a:

The Orion program issued a Justification for Other than Full and Open Competition (JOFOC) for Production and Operations (P&O) beginning with Artemis 3 and issued a Request for Proposals (RFP) to the contractor in January 2018. The Orion program is currently in negotiations and expects the sole-source contract with Lockheed Martin to be in place in the summer of 2019. The Orion production and operations prime contract will enable production of Orion spacecraft starting with Artemis 3 and is structured to provide nominally six, and potentially up to 12, spacecraft builds. The contract features major emphasis on full reuse of the Crew Module, with refurbishment, as early as possible. The contract will enable the Artemis 3 Orion spacecraft to be available for flight in 2024. In addition, NASA signed an Implementing Arrangement with the European Space Agency (ESA) to provide service modules for the Orion spacecraft for Artemis 1

and Artemis 2. Orion is in discussions with ESA about their continued contribution of service modules for the Orion spacecraft for Artemis 3 and subsequent missions.

For the SLS Program, a procurement action has been awarded to Boeing for Artemis 3 Core Stage long-lead material. Other SLS procurements to deliver Artemis 3 end item hardware are already on contract to support manifest planning. Procurements to deliver end-item hardware for Artemis 4 and subsequent flights have been awarded (RS-25 engines, Interim Cryogenic Propulsion Stage, and RL10 engines) or are in planning stages (Boosters, Core Stage, Exploration Upper Stage [EUS], RS-25 engines, and RL10 engines).

Question 3b:

When would you need to start work on EM-3,4, and 5 to ensure that NASA carries out an SLS launch once every year, as NASA has indicated it will do?

Answer 3b:

SLS has started work on Artemis 3 by initiating actions for Core Stage long-lead materials procurement. The procurement for Artemis 3 production must be awarded in FY 2019 to maintain schedule to support landing humans on the Moon in 2024. Procurement actions for other SLS end-item hardware (Boosters, RS-25 engines, and RL10 engines) may begin in FY 2020 for future missions.

Question 4-4a:

According to NASA's 2018 "National Space Exploration Campaign Report," the Lunar Gateway would enable basic scientific research. However, the recently transmitted Mars 2033 report, submitted pursuant to the NASA Transition Authorization Act of 2017, states that "Internal NASA planning documents... do not adequately justify why many of the scientific activities that may be conducted on the Gateway could not be performed using solely robotic means."

How is NASA justifying the potential use of the Gateway as a science platform?

Answer 4-4a:

The primary purpose of the Lunar Gateway project is to enable a sustained human presence on the surface of the Moon. While it is an exploration platform, the Lunar Gateway represents an opportunity for hosting science payloads, as well as providing infrastructure to support science activities in cislunar space (e.g., a communication relay for assets in lunar orbit or on the lunar surface). NASA intends to take advantage of this opportunity, just as it makes use of the International Space Station (ISS) as a platform for science missions; any potential impacts to the Gateway's primary exploration mission and logistics will be strictly minimized.

The results from a science workshop held last year showed that the Gateway in lunar orbit could support science missions in the fields of Heliophysics, Astrophysics, and Earth Science by conducting measurements that complement those acquired in Earth orbit. Use of the Gateway would not replace robotic spacecraft missions. Instead, it represents an additional opportunity to conduct science in a wide range of fields from a different vantage point.

Question 4b:

What criteria will NASA use to determine whether potential scientific investigations would be carried out on the Gateway?

Answer 4b:

The primary factor in determining which specific scientific investigations will be considered using the Gateway platform is alignment with science objectives called out in the various Decadal surveys. Other factors include 1) the scientific advantages of using the Gateway's elliptical near-rectilinear halo orbit, and 2) compatibility with the associated environment and operational resource needs (such as power, communications, and stability requirements). Any potential impacts to the Gateway's primary exploration mission and logistics will be strictly minimized.

Question 4c:

To what extent is the science community involved in decisions about the Gateway design and any potential use of the Gateway for science?

Answer 4c:

Since primary purpose of the Lunar Gateway is to enable a sustained human presence on the surface of the Moon, NASA does not expect that science needs would drive Gateway design. However, NASA is making sure that the science community is aware of Gateway plans and the potential use of the Gateway for science. A Gateway science workshop was held in 2018 with over 300 attendees from multiple science disciplines. Discussions at this workshop resulted in the identification of many high-value science questions that could be addressed by science investigations on or near the Gateway. Additionally, the National Academies of Science, Engineering and Math will be conducting a two-day Science on Gateway workshop this year to further define the science that can be accomplished using the Gateway platform.

Question 5-5a:

During the hearing, you testified that NASA will still carry out the "green run" test of the Space Launch System (SLS), but that you may modify "how much of a green run" is done.

Is your reassessment of the schedule for Exploration Mission I (EM- I) considering the possibility of not carrying out a full Green Run that would test the SLS core stage with all of the engines firing?

Answer 5-5a:

On July 25, 2019, NASA announced that it would conduct a "Green Run" engine test for the SLS rocket ahead of the upcoming Artemis 1 lunar mission.

During the Green Run testing, engineers will install the core stage that will send Orion to the Moon in the B-2 Test Stand at NASA's Stennis Space Center near Bay St. Louis, Mississippi for a series of tests over several months. The term "green" refers to the new hardware that will work together to power the stage, and "run" refers to operating all the components together simultaneously for the first time. Many aspects will be carried out for the first time, such as

fueling and pressurizing the stage, and the test series culminates with firing up all four RS-25 engines to demonstrate that the engines, tanks, fuel lines, valves, pressurization system, and software can all perform together just as they will on launch day.

The test program for the core stage at Stennis will begin with installing the stage into the test stand. Then, engineers will turn the components on one by one through a series of initial tests and functional checks designed to identify any issues. Those tests and checks will culminate in an eight-minute-long test fire, mimicking the full duration of the stage's first flight with ignition, ascent and engine shutdown. The results of this test also will provide important data that will confirm how the system reacts as the fuel is depleted from the propellant tanks.

The SLS program is performing the stage testing with flight hardware. Once the validation of the stage is complete, the entire stage will be checked out, refurbished as needed, and then shipped to NASA's Kennedy Space Center in Florida for the Artemis 1 launch.

Question 5b:

Have you consulted the Aerospace Safety and Advisory Panel on any potential changes to the test program for SLS and Orion, and if so, what was their advice?

Answer 5b:

NASA plans to keep the Aerospace Safety Advisory Panel apprised if there are major changes to the SLS/Orion test program.

Question 6:

The report, "Evaluation of a Human Mission to Mars by 2033," submitted pursuant to the NASA Transition Authorization Act of 2017, found that "NASA's current Human Research Program Integrated Research Plan to study human health risks associated with long-duration deep space spaceflight lacks sufficient detail in both evidence and strategy to justify the predicated timeline to develop risk mitigation strategies." It also noted concerns that the understanding and mitigation of human health risks by the 2030s may not be sufficient to meet risk standards or ensure crew survival on an extended mission. What is the rationale for requesting flat funding for NASA's Human Research Program from FY 2020 through FY 2024?

Answer 6:

The President's FY 2020 Budget Requests supports a robust NASA Human Research Program (HRP), which has developed an overarching space human health risk architecture that focuses its research on the highest risks associated with future human exploration missions. Since crew health and performance is critical to successful human exploration beyond LEO, HRP intends to fully utilize ISS and implement a ground-based national research program to mitigate crew health and performance risks and provide essential countermeasures and technologies for human space exploration. Crew health and performance risks include physiological effects from radiation, hypogravity, and confined spacecraft environments, as well as unique challenges in medical support, human factors, and behavioral health support. To efficiently manage the required research activities, HRP utilizes an Integrated Research Plan (IRP) to identify the approach and research activities planned under each risk area. Further, NASA HRP reports the progress in reducing the risk in the 28 human health and performance areas important to deep-

space exploration on the Path to Risk Reduction chart. The Integrated Path to Risk Reduction chart can be accessed at the website below:

https://humanresearchroadmap.nasa.gov/intro/

Based on the current success-oriented NASA HRP path to risk reduction plan, and assuming continued favorable outcomes of the primary investigations during ISS six-month missions, most of the human health and performance risks should be sufficiently mitigated by the time the ISS is retired. At this time, recently discovered visual changes and associated edema in the head tissues of astronauts are still being investigated and assessed to understand the risk, but may require additional ISS testing and countermeasure development. Future planned HRP research activities during additional ISS one-year missions will help us better understand the effects of longer exposure to the space environment and feed-forward to better protect crew health and safety on Mars missions.

Question 7:

The FY 2020 request includes, for the second year, $150M for the LEO Commercial Development Program, initiated in FY 2019. What specific objectives would this program address, and what is the basis for requesting $150M to achieve these objectives? Please provide any analysis to support the $150M request.

Answer 7:

The President's FY 2020 Budget requests $150 million for NASA's Commercial LEO Development effort, which is intended to stimulate both the development of commercially-owned and -operated LEO destinations from which NASA can purchase services, and the continued growth of commercial activities in LEO such that NASA is but one of many users purchasing those services. The Commercial LEO Development program will address policy, enabling commercial supply, and enabling demand. For example, in FY 2018, NASA entered into agreements with twelve industry partners to study the commercialization of LEO. These studies, which were funded by the ISS program, were designed to solicit industry's commercialization concepts, business plans and viability for habitable platforms in LEO, whether using ISS or free flying, that would enable a commercial marketplace in LEO where NASA is one of many customers. To enable the supply of commercial space station services, NASA will work with commercial partners on development of capabilities that could serve the needs of the private sector, NASA, and others around the globe. NASA has developed an integrated five-point plan incorporating these elements for the commercial development of LEO. The plan was rolled out at the NASDAQ stock exchange in New York on June 7, 2019, and details are available on the website www.nasa.gov/leoeconomy. Key elements of the plan are summarized below:

1. Establish ISS commercial use and pricing policy
    - A NASA Interim Directive was put in place on June 6, 2019, outlining new use and pricing policies intended to enable demonstration of new markets.

2. Enable private astronaut missions to ISS
    - ISS is prepared to accommodate two private astronaut missions per year beginning early in FY 2021, stimulating demand for commercial crew services and enabling new commercial activities. NASA has issued a new focus area under the ISS Utilization NASA Research Announcement (NRA) to create an

avenue for companies to pursue private astronaut missions.

3. Initiate process for commercial development of LEO destinations
    - NASA is partnering with industry on a two-pronged approach to develop commercial destinations, attached to the ISS initially, and as a free-flyer destination. To do this, NASA will conduct two open competitions supporting the development of commercial LEO destinations in FY 2019. Both will be conducted using the NextSTEP-2 Broad Agency Announcement. The first competition, Appendix I, will pursue public-private partnerships to develop LEO destinations that could be module(s) and/or platform(s) attached to the ISS. The second competition will pursue public-private partnerships to develop LEO destinations that are free flying in LEO. NASA intends to select winning proposals and make initial awards prior to the end of 2019.

4. Seek out and pursue opportunities to stimulate demand
    - NASA is partnering with industry to stimulate demand through a variety of partnerships and acquisition mechanisms. These include two focus areas in the ISS Utilization NRA focused on manufacturing and space laboratories, as well as Appendix J of the NextSTEP-2 Broad Agency Announcement to seek innovative approaches to broadly stimulate sustainable demand.

5. Quantify NASA's long-term needs for activities in LEO
    - NASA's demand forecast has been quantified and released on June 7, 2019, to reduce industry uncertainty in developing business models.

Question 8:

Does the FY 2020 request and 5-year projection include funding to initiate the work on the next high-priority missions recommended in the most recent Earth science decadal survey and the project to be recommended by the 2020 Decadal Survey for Astronomy and Astrophysics? If so, how much funding is proposed, and in what year would "new starts" begin?

Answer 8:

The 2017 Earth Science Decadal Survey identified five categories of "Designated Observables" as the highest priority measurements for the next decade of NASA Earth Science. However, these do not necessarily translate to five new missions. NASA is currently engaging in studies to develop concepts for potential observing system architectures that would address the Designated Observables. NASA is intentionally referring to these as "observing systems," since the architectures could range from a single dedicated mission to a disaggregated constellation of several satellites/instruments and include international partnerships or payload/instrument hosting on commercial systems. The five-year projection in the FY 2020 request is sufficient to initiate at least one new Designated Observable observing system in FY 2021. The Astrophysics projection has about $100 million per year starting in FY 2022 to start new missions, which could include a new medium mission or probe mission from the 2020 Decadal Survey.

Question 9:

The FY 2020 budget request proposes a 20 percent reduction in NASA Astrophysics and

JWST (combined). Given that reduction, as you testified in response to a question by Representative Beyer, "the only way to [start another flagship mission in Astrophysics] would be to cannibalize a lot of smaller-class missions and medium-class missions." The budget request therefore proposes terminating one top-priority flagship science mission, the Wide Field Infrared Survey Telescope (WFIRST) in the Astrophysics Division, while also proposing to initiate a different high-priority science mission, Mars Sample Return, in the Planetary Science Division. Both divisions have top-priority flagship missions in the final phases of integration and testing (JWST and Mars Rover 2020, respectively). What criteria were used to inform the proposals to reduce the Astrophysics budget and terminate WFIRST, but initiate Mars Sample Return in the FY 2020 budget request?

Answer 9:

The Agency's strategic plan issued in February 2018 emphasizes achievements aligned to the three strategic themes of Discover, Explore, and Develop, as well as a fourth theme focused on the activities that will Enable our Mission. It provides the foundation for a U.S.-led return to the Moon for long-term exploration and use and to establish a foundation for eventual crewed missions to Mars and potentially beyond. The budget proposes to terminate funding for the Wide Field Infrared Survey Telescope (WFIRST) mission and focus on the completion of the James Webb Space Telescope (JWST), now planned for launch in 2021. Due to the significant cost of funding both JWST and WFIRST at the same time, funds would have needed to be redirected from other programs, disrupting the balance of the overall science portfolio.

Question 10:

NASA's scientific data archives contain tens of petabytes of data and are predicted to store hundreds of petabytes by 2025. What are NASA's plans for managing its growing archive of data? What, if any, funding is proposed in the FY 2020 budget request to address data storage and management, and what, specifically, would be funded?

Answer 10:

In light of the anticipated exponential growth of scientific data over the next few years, SMD is undertaking a strategic effort to define our data storage and management needs over the next five years. We are taking a holistic approach to our data ecosystems and working on ways to improve the connectivity, discoverability, functionality, and user experience for the available data and the tools necessary to create valuable science products from that data. We are also assessing the available computing resources in light of current and future demand. This effort is being informed by recent recommendations from the NASA Advisory Council's Science Committee and the National Academy of Science, Engineering, and Medicine, and input from the user community. This strategic planning effort will be completed this summer and will be used to inform future budgets.

The FY 2020 budget request contains approximately $165 million to support data archiving, curation, and management across the entire Science Mission Directorate. The modernization efforts we are currently undertaking with this funding include:

- Exploring the potential of cloud environments to improve scientific productivity and enable new approaches to data-based science through focused pilot projects and longer-term agreements. Such capabilities provide state-of-the-art scientific computing

capabilities with low capital investment while simultaneously reducing the scientific data management burden for operators and users of public data.
- Soliciting the development of open source software and tools to be used in conjunction with science data through the Research Opportunities in Space and Earth Sciences (ROSES) NASA Research Announcement (NRA).

Developing platforms and server-side analysis to meet user needs for computing facilities "near the data," rather than the lengthy process of copying data to a scientist's workstation. This can be done via cloud computing and bibliographic databases.

Question 11:

The FY 2020 budget request proposes to move aeronautics facilities funding and management out of the Aeronautics Research Mission Directorate and into Safety, Security, and Mission Services. What is the basis for NASA's expectation that this would "improve the overall efficiency and effectiveness of managing Agency Test Capabilities?"

Answer 11:

NASA's wind tunnels are unique national assets and the Agency is committed to maintaining, modernizing, and enhancing the Aeronautics Evaluation and Test Capability (AETC). Prior to FY 2017, AETC received a portion of its annual funding directly from the Aeronautics Research Mission Directorate (ARMD). The rest was expected to be paid for by the users of the wind tunnels. Under this model, the ultimate funding total for AETC each year was unknown. Managers were forced to focus on how to cover their operating expenses for the year, and there was little investment made in enhancing or modernizing the capability. To provide funding stability and enable AETC to plan and invest in the capability, the FY 2017 budget included sufficient direct funding to cover AETC's operating expenses and projected the funding level to grow in subsequent years for investments in modernization and enhancements. The most consistent user of AETC is the ARMD, but projects in SMD, the Human Exploration and Operations Mission Directorate, and the Space Technology Mission Directorate all utilize the capability from time to time. To acknowledge the benefits to the entire Agency, the FY 2017 Budget included direct funding in four appropriations accounts.

NASA executed the budget for AETC this way for FY 2017 and FY 2018. However, our initial estimates for how much each account would use AETC did not align with actual data, making it necessary to transfer AETC funds between appropriations in order to achieve the proper balance. Under the FY 2017 model, such transfers would be required near the end of every fiscal year. In addition to posing an administrative burden to Congress, AETC and the relevant NASA Centers, this situation also introduces risk to the Agency. If transfers between various appropriations accounts were delayed beyond the end of a fiscal year or not made at all, the Agency could inadvertently fail to comply with fiscal law. Therefore, NASA made the decision to continue to provide the full annual AETC funding level, but to do so from a single source.

The Shared Capabilities and Assets Program (SCAP) in the Safety, Security, and Mission Services account ensures select critical test facilities are operationally ready to meet mission and program requirements from across all of NASA's appropriations by sustaining a skilled workforce and performing essential maintenance. The program already supports essential core technical capabilities: arc jets, simulators, thermal vacuum chambers, and space radiation environments. AETC is a natural fit in this program, and so the Agency decided to consolidate the funding from across the missions into this line.

Question 12:

The proposed reorganization of the Space Technology Mission Directorate (STMD) in the FY 2020 budget request would focus STMD projects on lunar and deep space exploration. What, if any, science-related space technology projects would be continued under the proposed space technology activities in the Exploration Technology account and which science-related projects, if any would not be continued? Would Exploration Technology activities include work on space-based coronagraphs for exoplanet direct imaging?

Answer 12:

Exploration Technology continues to work with SMD, where appropriate, on exploration-related technology and research that also has relevance to achieving science goals. Exploration Technology will continue to invest in science-related early-stage technologies through programs such as the Small Business Innovative Research (SBIR), NASA Innovative Advance Concepts (NIAC), and Space Technology Research Grants (STRG). Exploration Technology will continue to develop technology maturation and demonstration activities that provide advance capabilities that also benefit future science-related missions, including Deep Space Optical Communications, In-Space Robotic Manufacturing and Assembly, and Deep Space Atomic Clocks. The FY20 budget request does not include funding for WFIRST or for the technology demonstration of a space-based coronagraph for exoplanet direct imaging.

Question 13-13a:

The FY 2020 budget request would involve a significant shift in NASA's communications architecture with the proposed initiation of a Communication Services Program.

Why is this program being proposed before NASA has transmitted to Congress the report mandated in Section 304 of the NASA Transition Authorization Act of 2017, which calls for a space communication plan for LEO and deep space operations over the next twenty years and was due on March 21, 2018?

Answer 13-13a:

Planning for this program began in FY 2019 in order to provide enough time for it to prove out an initial set of commercial communications services that can meet NASA's needs by the time the oldest operating TDRS communications relay satellites need to be retired. Precise retirement dates are difficult to estimate in advance but will likely be reached in the mid-2030s. In order to more accurately reflect the Administration's vision for commercially-provided space communications, NASA has delayed transmission of its 20-year space communication and navigation plan until release of the President's FY 2020 budget. The draft plan is currently under internal review to ensure that all communication and navigation needs for NASA's missions over the next decade can be met.

Question 13b:

On what date will you transmit the overdue Section 304 report?

Answer 13b:

The Section 304 report is under review in order to accurately reflect changes to the Program. NASA expects to transmit the report before the end of 2019.

Question 14-14a:

During the question and answer session of the hearing, you referenced the assessments that NASA has done in conjunction with NOAA that determined that the noise threshold set by the FCC for its auction of 24GHz spectrum presents a high risk of interference with Earth remote sensing data in adjacent spectral bands.

Please provide a copy of the assessments by NASA and NOAA to the Committee.

Answer 14-14a:

NASA would be pleased to provide a copy of the joint assessment performed by NASA and the National Oceanic and Atmospheric Administration (NOAA) after all technical analysis is verified.

Question 14b:

What is NASA's plan moving forward to mitigate the risk of interference caused by 5G spectrun expansion in the 24GHz band and elsewhere?

Answer 14b:

NASA continues to engage in technical discussions regarding the 24 GHz band with representatives from the Federal Communications Commission (FCC), NOAA, the National Telecommunications and Information Administration, and the Department of State, so all parties can gain a better understanding of NASA and NOAA mission operations, the levels needed to protect these weather and science systems, and the FCC's interference threshold used for the auction.

Question 15:

In response to Representative Beyer's question on the proposed termination of the Wide Field Infrared Survey Telescope (WFIRST), currently in development, in the FY 2020 budget request, you stated that WFIRST "needs to work in conjunction with James Webb.

How does NASA plan to carry out the overlap of WFIRST and James Webb Space Telescope (JWST) operations?

Answer 15:

JWST and WFIRST have complementary capabilities. Together, they provide very powerful probes of our universe's evolution; however, neither is required for the operation of the other and each can stand on its scientific merit alone.

JWST and WFIRST address questions about the formation and evolution of the universe in different ways. JWST studies smaller fields of view in unprecedented depth, including, for example, the earliest stars and galaxies and atmospheres of exoplanets. WFIRST studies large samples of galaxies at all epochs to better understand overall cosmic evolution and understand

how our universe came to be, and can use its wide field of view to discover rare objects.

In addition, JWST has the largest collecting area for any existing or proposed space telescope, and therefore has the sensitivity to image very faint objects in narrow fields of view of the sky. WFIRST, on the other hand, has the sensitivity of Hubble but can take pictures with a field of view about 100 times larger than that of Hubble.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:

Administrator Bridenstine

Submitted by Congresswoman Bonamici

Question 1:

During the hearing you mentioned that you would follow up for the record on a question I asked regarding the distinct value of the PACE mission. Please respond with a detailed list of other federal government and international satellite efforts that are providing or will provide similar results for ocean and atmospheric observations if the PACE mission is eliminated.

Answer 1:

The Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE) mission builds on the legacies of NASA missions currently on orbit (e.g., the Moderate Resolution Imaging Spectroradiometer [MODIS] instrument on Aqua and Terra and the Visible Infrared Imaging Radiometer Suite [VIIRS] instruments on Suomi-NPP and National Oceanic and Atmospheric Administration-20 [NOAA-20]) and several international efforts (e.g., the Ocean and Land Colour Instrument [OLCI] instrument on the European Space Agency/EUMETSAT Sentinel-3A and -3B missions). These satellite instruments, as well as PACE, all provide global ocean color, cloud, and aerosol data records at a nominal ~1-kilometer spatial resolution every two to three days. These current capabilities are multi-spectral instruments that measure only several wavelengths of light and are not identical to what the PACE mission would provide.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:
Administrator Bridenstine
Submitted by Congresswoman Horn

Question 1:

The FY 2020 NASA budget proposal for returning to the Moon assumes the use of public- private partnerships and commercial capabilities. What are the criteria by which NASA is determining whether to use commercial launch vehicles, commercial landers, or commercially-developed elements of the Lunar Gateway?

Answer 1:

NASA has pioneered the implementation of a wide variety of innovative acquisition approaches targeted at enabling challenging missions, advancing national industrial capabilities, and managing Government exposure to cost and schedule risks. NASA's strategy is to leverage the full range of acquisition approaches to enable the success of the Exploration Campaign at the best value to the taxpayer.

NASA is planning to develop a series of progressively more capable missions to the surface of the Moon, utilizing public-private partnerships and international participation to promote innovative approaches to lunar robotics, a cislunar presence, and lunar landing capabilities to enhance U.S. leadership.

- Advanced Exploration Systems will invest in development and demonstration of exploration capabilities to reduce risk, lower life cycle cost and validate operational concepts for future human missions. By leveraging the Next Space Technologies for Exploration Partnerships-2 (NextSTEP-2) Broad Agency Announcement (BAA), NASA is able to execute public-private partnerships in a timely manner. NASA is utilizing this innovative and flexible contract vehicle as a public-private partnership mechanism for maturing key enabling technologies that are integral to NASA's campaign to return to the Moon. Ground habitation prototypes developed through NextSTEP-2 will be tested to evaluate human factors for different habitat configurations; assess how the various systems interact together and with other capabilities like propulsion modules and airlocks; and provide platforms to test and ensure that standards and common interfaces being considered are well designed.

- In 2017, NASA also utilized the NextSTEP-2 BAA for studies on approaches to the Power and Propulsion Element (PPE), including potential for

leveraging commercially available capabilities and potential commercial interests. In September 2018, NASA released a solicitation for Spaceflight Demonstration for PPE, and in May 2019, selected Maxar Technologies. PPE is being developed as a public-private partnership leveraging industry capability and plans, demonstrating high-power solar-electric propulsion. In the solicitation, NASA specified only its unique requirements, allowing the industry partner to include their own objectives and requirements. The partner would own PPE through launch and an on-orbit demonstration lasting up to one year, after which NASA would have the option to acquire the PPE for use as the first element of Gateway.

- Gateway and NASA's Advanced Cislunar Surface Capabilities programs will be utilizing a variety of agreements and contracts that enable NASA and private industry as well as academia and international partnerships to share in the risk and gain of Government investments. These shared risks and gains include incentivizing technical performance, building future commercial markets and a shared financial interest in developing capabilities. For example, using NextSTEP-2, NASA has also already solicited, and received, industry proposals for elements of the Human Landing System (HLS), and is currently evaluating and weighing the merit of these offers. There are currently NextSTEP-2 contracts that have delivered to NASA ground-based, deep space habitat prototypes. Ongoing NextSTEP-2 partnerships are advancing the state of the art in on-orbit additive manufacturing, advanced environmental control and life support systems, waste management, and logistics reduction. In addition to providing NASA with required capability for lunar and deep space exploration, these public-private partnerships are assisting in the development of a robust American space economy.

NASA's determination of the proper mix of in-house vs. commercial capabilities will be informed by a number of factors, depending on the specific technical areas involved, but the Agency plans to continue to promote the development of a commercial space economy with full engagement from industry.

Question 1a:

Has NASA conducted cost-benefit analyses on the use of multiple commercial vehicles to launch elements of the Gateway versus using SLS?

Answer 1a:

The Lunar Gateway will be launched on competitively procured commercial launch vehicles and assembled in orbit around the Moon where it will be used immediately as a staging point for missions to the lunar surface. It can evolve depending on mission needs, and will support human-class reusable landers, landing a crew of up to four astronauts on the lunar surface and ultimately developing sustaining lunar operations on the Moon. Delivery of Lunar Gateway and lunar lander elements, including refueling of these elements, will create a reusable hub for sustainable lunar

activity and feed forward to Mars. In general, the cost to the government of a single SLS launch exceeds the cost of all commercial launch vehicles by hundreds of millions of dollars. However, the SLS offers capabilities that no existing commercial launch vehicle can replicate. Therefore, NASA plans to use SLS for missions for which its unique capabilities are required and use less expensive commercial launch vehicles for all other missions, consistent with the U.S. National Space Transportation Policy.

SLS will play an instrumental role in carrying out the Exploration Campaign objectives, as a critical component for delivering crew to the Lunar Gateway. The Agency will continue to identify and implement affordability strategies to ensure SLS can be a sustainable exploration capability for decades to come.

Question 2:

NASA's human spaceflight program has, for decades, involved low Earth orbit (LEO), including previous Shuttle missions and International Space Station exhibitions. How many LEO space suits does NASA currently have? How many of those suits can support extravehicular activities? What is the design-life of those suits and when will they need to be replaced?

Answer 2:

The current space suit used on the ISS is called the Extravehicular Mobility Unit (EMU). It is comprised of an anthropomorphic pressure garment (typically called the Space Suit Assembly or SSA) and the "backpack" which provides all the life support functions (typically called the Primary Life Support System or PLSS).

The modern day EMU fleet life began in 1978 during the Space Shuttle Program. These suits were originally certified with a life duration of 15 years. In the 1990s, NASA selected the EMU for use in assembling the ISS in lieu of developing a new design to meet the unique mission needs for the International Space Station (ISS) program. In 1993, the Agency commenced a life extension program referred to as the Assured EMU Availability (AEA) effort to methodically determine necessary steps for extending the life well beyond the original 15-year certification. Through this effort, components are certified for life extension, refurbished, or replaced, as necessary. Eighteen flight PLSS units were built since the inception of the EMU design, with the last unit delivered to NASA in 1999. Today, 11 flight units remain in inventory and are used supporting the ISS program, with typically four of these units on ISS at any one time.

As documented in the Advanced Space Suit Capability Plan delivered to Congress in June 2017, NASA is replacing some of the key components of the current EMU with the latest technology that will be used in the advanced space suit demonstration onboard the ISS. Components such as the carbon dioxide monitor and battery pack are being replaced. With the ongoing upgrades to the current EMU suit, at this time NASA does not believe there is a need for immediate initiation of a traditional acquisition to replace the heritage EMU on ISS.

Question 3:

Any return to deep space exploration will require space suits that can support crew, including crew visits to the lunar or Martian surface. Are lunar surface suits extensible to Mars or are different designs needed? What is NASA's plan for developing deep space suits and how will that plan change under a program that would send astronauts to the lunar surface in 5 years?

Answer 3:

In June 2017, pursuant the NASA Transition Authorization Act of 2017 (P.L. 115-10), NASA submitted to Congress its Advanced Space Suit Capability Plan. As the Agency works to determine the optimal approach to a human lunar landing by 2024, plans for the development of new suits for exploration will be revised. The space suits to be used for lunar surface exploration will have many components and technologies in common with those that will eventually support astronauts on the surface of Mars, and the Agency plans to take advantage of those commonalities. As there are differences between the lunar and Martian surface environments (e.g., characteristics of the dust), the Mars EVA suits will include elements tailored for that environment.

Question 4:

The FY 2019 budget proposed to end direct U.S. financial support for the International Space Station in 2025. Has anything changed in the FY 2020 budget request?

Answer 4:

NASA will continue its mission in low-Earth orbit (LEO) with the ISS to enable exploration with humans to the Moon and on to Mars, continuing to perform research that benefits humanity, supporting National Lab research by private industry and other organizations, and working towards reducing operations and maintenance costs. The Commercial LEO Development effort is providing resources for NASA to assist industry in developing a commercial LEO presence, with and without crews. Once these new commercial capabilities have been deployed in orbit, NASA will begin transitioning LEO operations to private industry. Together, NASA's ISS and Commercial LEO Development efforts will lay the foundation for the emergence of an environment in LEO where NASA is one of many customers of a non-Governmental human spaceflight enterprise.

Question 4a:

What is your plan for operating the ISS after 2024?

Answer 4a:

NASA's Commercial LEO Development effort is intended to stimulate both the development of commercially owned and operated LEO destinations from which

NASA can purchase services, and the continued growth of commercial activities in LEO where NASA is one of many users purchasing those services. As those commercial LEO destinations are available, and without a gap in human presence in LEO, NASA intends to implement an orderly transition from current ISS operations to the new commercial enterprise as laid out in NASA's ISS Transition Report of March 30, 2018. NASA will not have specific availability dates of commercial LEO destinations until the agency issues awards through the NextSTEP-2 BAA Appendices being used to support these destinations. The ISS Transition report may be accessed via the link below:

https://www.nasa.gov/sites/default/files/atoms/files/iss_transition_report_180330.pdf

Question 4b:

What does NASA plan to do in FY 20, 21, 22, 23, and FY 24 to transition from U.S. direct operations of the ISS?

Answer 4b:

Please see response to Question #4a, above. Further details can be found in the ISS Transition Report, which is updated biennially.

Question 4c:

What arrangements are you making with international partners regarding the end of U.S. direct financial support for operations?

Answer 4c:

One of NASA's ISS Transition Principles is to expand U.S. human spaceflight leadership in LEO and deep space exploration, including continuity of the relationship with our current ISS international partners. Consistent with the ISS Transition Principles, NASA will continue discussions with the ISS International Partners to help shape the long-term future of the ISS platform and LEO. Consultations with the ISS partners and stakeholders are essential to developing an implementation strategy that could result in the day-to-day execution of the ISS being performed by private industry. NASA is using the framework that currently supports cooperation on the ISS to facilitate partnerships on the lunar Gateway and on the surface of the Moon to ensure that current ISS partners have opportunities to collaborate with NASA on the full spectrum of future human exploration activities.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:

Administrator Bridenstine

Submitted by Congresswoman Sherrill

Question 1-1a:

The FY 2020 budget proposal would eliminate the NASA Office of STEM Engagement. The Office of STEM Engagement provides funding for eighteen institutions in New Jersey and over ninety-percent of award recipients have continued to graduate study or employment in STEM . You testified during the hearing that NASA supports other education initiatives through the mission directorates.

Please provide an accounting of the support for STEM initiatives in each of the other mission directorates.

Answer 1-1a:

NASA has a long history of engaging students in its mission through effective Science, Technology, Engineering, and Math (STEM) engagement activities and programs. NASA's endeavors in STEM engagement began early on, driven by the language in Section 203 (a) (3) of the Space Act which directs NASA "to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof, and to enhance public understanding of, and participation in, the Nation's space program in accordance with the NASA Strategic Plan."

While the FY 2020 budget proposes to eliminate the Office of STEM Engagement (OSE), it is important to understand that STEM education and outreach efforts have always occurred beyond the walls of the Education Office (e.g., internships and fellowships managed by our Mission Directorates, our Speaker's Bureau which sends NASA scientists and engineers to meet with educational and civic organizations, and NASA employees who are authorized to use work hours to mentor local students in STEM activities). Therefore, even if OSE is eliminated, 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. (Please see the attached spreadsheet for examples of STEM work managed by NASA's Mission Directorates.)

Following the elimination of OSE, NASA would staff a small, focused functional office at NASA Headquarters to be accountable for the strategic direction and coordination of the cross-Agency STEM engagement efforts, including more closely aligning Agency STEM efforts with our Mission Directorates and their missions. This would serve to better inspire students by having them work on real-world missions and problems, which in turn directly impacts NASA missions.

Fully recognizing the importance of its STEM mission, NASA has spent the last two years analyzing ways to optimize Agency STEM efforts as a whole. For example, NASA recently completed a deep-dive assessment of the Agency's Education and Outreach efforts, known as a Business Services Assessment (BSA). During this assessment, a core team collected data from across NASA, conducted surveys and interviews with internal and external stakeholders, benchmarked external organizations and performed a detailed assessment of existing Education and outreach efforts. Based on this analysis, NASA created a more seamless approach to eliminate redundant functions and duplication of efforts, and fill in existing gaps in order to better serve the STEM engagement community. It also established the STEM Engagement Council (SEC), which is the Agency's governance body accountable for NASA's comprehensive set of STEM engagement functions and activities. Building on the BSA work, OSE is currently undergoing a Mission Support Future Architecture Program (MAP) Project to realign the mission support structures to improve efficiency in order to implement an integrated STEM function with a unified approach that will provide a higher return for NASA missions and the Nation's future STEM workforce.

As further proof of NASA's dedication to STEM outreach, it is important to note that NASA Administrator Bridenstine recently established the NASA Advisory Council STEM Engagement Committee in order to provide consensus advice and make recommendations regarding NASA's important role of inspiring the next generation and having it be recognized by the whole of Government. Committee Members represent external STEM stakeholders such U.S. universities and museums and industry associations. NASA is also actively supporting the National Science and Technology Council's Committee on STEM Education endeavors, with NASA Administrator Bridenstine serving as the Committee's Co-Chair. The Committee's recent report, *Charting a Course for Success: America's Strategy for STEM Education*, lays out the federal Government's role in furthering STEM education by working with state, local, education, and American employer stakeholders to build a STEM-proficient citizenry, create a STEM-ready workforce and remove barriers to STEM careers, especially for women and underrepresented groups.

Question 1b:

What assessments of the NASA Office of STEM Engagement and education initiatives in the mission directorates have you completed to support the rationale for eliminating the Office of STEM Engagement?

Answer 1b:

Please see NASA's response to Question #1a.

Question 2-2a:

In New Jersey 28 percent of our awards go to minority and 43 percent go to female students. As this program positively impacts a diverse and broad reaching community of students:

Are any of the other education initiatives in the mission directorates specifically targeted to underrepresented and/or underserved communities?

Answer 2-2a:

NASA STEM activities both disseminate knowledge of the Agency's advances in science, technology, aeronautics and space exploration, and support the creation of knowledge by learners, educators, and institutions. NASA Offices, Mission Directorates, Centers, and Facilities collaborate to implement a single Agency-wide approach to STEM education. This approach provides unique NASA experiences to learners, educators, and institutions, as well as streamlined access to NASA content, websites, people, resources, and facilities.

Building a strong STEM workforce for the 21st century and beyond requires the development of a stronger and more diverse pipeline for STEM, including women and individuals from other underrepresented and underserved groups. To maintain a globally competitive Nation, our education programs develop and deliver activities that support the growth of NASA's and the Nation's STEM workforce, help develop STEM educators, engage and establish partnerships with institutions, and inspire and educate the public.

Most of NASA's current data regarding its STEM outreach efforts focuses on outputs of its education activities (e.g., number of students and educators reached). NASA will continue to monitor its efforts to share the STEM message with diverse groups, including women and individuals from underrepresented and underserved groups, pledging to use these results as a stepping stone for improved and expanded STEM outreach efforts. To this end, NASA is working on capturing improved data on demographics, while recognizing that demographics identification at NASA events is voluntary. Additionally, NASA will continue to engage the public and other key stakeholders in its activities, and work to build an open, transparent and participatory organization. Through strategic use of NASA assets in its STEM education offerings, NASA will share its inspirational activities with a broader audience.

Question 2b:

Has NASA analyzed the demographics of the participants in the initiatives in the mission directorates and the Office of STEM Engagement programs?

Answer 2b:

Please see NASA's response to Question #2a.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Perlmutter

Question 1:

How are current and future scientific research and development requirements being incorporated into the development and execution of both LEO commercialization and ISS transition plans?

Answer 1:

NASA will continue research and technology efforts in low-Earth orbit (LEO) using the International Space Station (ISS) to enable exploration with humans to the Moon and on to Mars, while continuing to perform research that benefits humanity and leads to a robust ecosystem in LEO, supporting ISS National Lab research by private industry and other organizations, and working towards reducing operations and maintenance costs. NASA is working to implement a step-wise transition of ISS from the current regime of NASA sponsorship and direct NASA funding, to a regime where NASA is one of many customers purchasing services from a LEO non-Governmental human space flight enterprise. NASA will gradually transition from current ISS operations to this new regime to ensure that the United States always has access to a crewed space station in LEO. As part of this transition, NASA plans to purchase needed LEO services from a commercial operator of ISS and/or new commercial LEO destinations. The full transition from ISS to new commercial LEO destinations will be gradual.

Over the next several years, the research program will continue to focus on capabilities needed to maintain a healthy and productive crew in deep space. Manifested or planned experiments and demonstrations to enable human exploration at the Gateway, lunar surface and into deep space include tests of improved long-duration life support, advanced fire safety equipment, on-board environmental monitors, techniques to improve logistics efficiency, in-space additive manufacturing, advanced exercise and medical equipment, radiation monitoring and shielding, human-robotic operations, and autonomous crew operations.

NASA has also developed and released to the public a forecast of future NASA demand for services in LEO. This forecast, which includes both research and technology development requirements, is intended to inform ISS transition and LEO commercialization efforts. It is available here: https://www.nasa.gov/leo-economy/long-term-needs.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:
Administrator Bridenstine
Submitted by Congressman Tonko

Question 1:

What kind of research, development and demonstration is being done at NASA related to using hydrogen as a fuel?

Answer 1:

Hydrogen in liquefied form (LH2) has been utilized by NASA for decades as a rocket fuel for both main and upper stages of vehicles such as the Saturn V and Space Shuttle, and will be used in NASA's Space Launch System when it is complete. To date, every LH2-powered flight vehicle has used the propellant close to its normal boiling point (i.e., in equilibrium with the atmospheric pressure); however, over the years NASA has investigated the possibility of boosting the energy density of LH2 via different processes by cooling the liquid and/or producing slush mixtures. Recently, the Advanced Exploration Systems (AES) Division funded a research and development effort at Kennedy Space Center (KSC), in collaboration with Glenn Research Center (GRC) and Stennis Space Center (SSC), aimed at demonstrating next-generation liquid hydrogen technologies and operations on a large scale (i.e., relevant scale to a launch pad architecture). This system, deemed the Ground Operations Demonstration Unit for Liquid Hydrogen (GODU-LH2), employed the NASA-pioneered Integrated Refrigeration and Storage (IRAS) technology to achieve such milestones as long-duration, zero-loss storage of LH2, zero-loss LH2 tanker offloads, *in situ* liquefaction, and densification of hydrogen down to the freezing point. In fact, the GODU-LH2 testing resulted in the single largest batch of solid hydrogen ever produced.

Question 1a:

How much is being spent?

Answer 1a:

Over the preceding 5 years approximately $13.5 million has been spent on the research and technology development work described in the response to Question #1. There is currently no planned FY 2020 funding for continuation of this research or application of this capability. The research and development effort for the IRAS has matured the technology to the point where other NASA programs/projects may choose to infuse the new technology.

Question 1b:

Is NASA partnering with other federal agencies or Departments?

Answer 1b:

Yes, NASA cooperates and has ongoing partnering activities with the departments of Energy, Defense, and Transportation (DOE, DOD, and DOT). NASA also participates on the Inter-Agency Power working group (IAPG) where information on research activities is exchanged on a quarterly basis. Research coordination is most active with the U.S. Army, DOE, and the U.S. Navy.

Question 2:

What NASA investments are being made in hydrogen technologies as it relates to generation, distribution, compression or storage to meet NASA's mission needs and requirements?

Answer 2:

NASA continues to conduct research on cryogenic transfer of propellants and feasibility studies for utilizing terrestrial electrochemical technologies in space applications. In addition, NASA is conducting ongoing development and demonstration of technologies to enable cryogenic liquefaction and storage of hydrogen; electrochemical generation and consumption of hydrogen using electrolyzers, fuel cells and regenerative fuel cells for terrestrial, aeronautic, and space applications.

For example, NASA's Evolvable Cryogenics and CryoFluid Management projects are developing, validating, and integrating cryogenic fluid management technologies at a scale relevant for possible infusion into a variety of future space vehicles and space systems, including future missions to the lunar surface.

Because cryogenic propellants need to be stored at ultra-low temperatures, handling and storing propellants such as hydrogen can be difficult. Energy, in the form of solar radiation and heat conducted by the rocket structure itself, continuously threaten to raise fuel temperatures, causing the fluid to evaporate, or "boil off," making it unusable as a propellant. Current technologies seek to rid the fluids of this persistent threat, keeping them cold by boiling or evaporating away the heat energy. These projects are developing additional solutions for in-space storage and transfer of cryogenic propellants that are more efficient when it comes to energy use, cost, and mass, which could benefit a range of extended science and exploration missions throughout the solar system. For example, the eCryo project will begin its Structural Heat Intercept-Insulation-Vibration Evaluation Rig (SHIIVER) testing in July 2019 to demonstrate the effectiveness of new multi-layer insulation, and evaluate the potential benefit of using vapor vented from a propellant tank to intercept heat coming into the tank through structural elements. Both of these efforts will allow the Agency to use hydrogen more efficiently.

Question 3:

Commercial and retail users have expressed concerns about reliability with hydrogen supply. For example, there are instances in California where retail hydrogen stations have, sporadically, not had adequate supply to fuel cell electric vehicles. Is NASA experiencing any hydrogen supply reliability issues? If so, what impacts are the hydrogen supply issues having on NASA's programs and plans?

Answer 3:

NASA contracted liquid hydrogen supply has been reliable. During 2018, NASA's hydrogen suppliers began stating the market had tightened, but the only impacts to NASA have been to provide advance notice and to coordinate schedules and provide some coordination and deconflicting between Centers. This is typically during periods of high launch related demand at KSC in the same timeframe as high engine-testing demand at SSC.

Question 4:

Hydrogen is transitioning from primary use as a commercial/industrial gas to a transportation fuel and as an energy storage medium. How is NASA preparing for this transition as increasing hydrogen demand from the commercial/retail sector grows exponentially?

Answer 4:

Demand growth is expected but it is unlikely to be exponential. Hydrogen suppliers have announced construction of three new liquid hydrogen production plants that are expected to begin supplying product in 2021. NASA expects supplier production capacity to be sufficient to continue to obtain reliable supply in the future.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Foster

Question 1-1a:

NASA has primarily powered its deep space probes with radioisotope thermoelectric generators (RTGs) using Pu-238. It has recently been increasing efforts to develop fission reactors, which can provide both propulsion and power. NASA is currently developing nuclear thermal propulsion systems using low-enriched uranium (LEU), and nuclear reactor power systems using highly-enriched uranium (HEU). If all the spacefaring nations start using HEU reactors, then it would involve the utilization of a significant amount of weapons-grade material.

Could the U.S. lead the way in developing space-qualified reactor power system designs using LEU?

Answer 1-1a:

Yes, there is considerable U.S. expertise to develop a range of space reactor options. NASA and the Department of Energy continue to study both highly-enriched uranium (HEU) and low-enriched uranium (LEU) fuel types for space power reactors. There are certain mass constrained missions for which HEU likely presents the optimum solution when considering all factors, including reactors in the 10 kW class (or less) that could serve robotic lunar landers and deep space science probes. In this class, the mass penalties for using LEU would likely negate the benefits of nuclear power since the landers and spacecraft that could use these fission power sources have significant payload capacity constraints. Current estimates indicate a 50 to 100% mass increase for a 10 kW LEU system versus a 10 kW HEU system, and the LEU option would require a new fuel system development compared to using existing capabilities. If mission power requirements reach above several 100 kW, the mass penalty for LEU can generally be accommodated without compromising mission objectives. The development of such a reactor would need to be supported by commensurate launch vehicle, lander, and spacecraft designs with sufficient payload capacity for the larger reactor systems.

Question 1b:

If the U.S. develops such a design, is it reasonable to believe it would be adopted as a de facto standard by other spacefaring nations?

Answer 1b:

Some other spacefaring nations, such as Russia and China, have their own space fission development plans which likely include HEU fuel options. Recent studies on space fission power sources by the European Commission, such as the Democritos Nuclear Electric Propulsion mission concept, indicated plans for partner country Russia to supply an HEU-fueled reactor. Few other nations have expressed interest in using a reactor for space exploration due to the cost and complexity. If interest is expressed by our international space partners, NASA could lead the way in developing a multi-mission LEU reactor option so long as U.S. International Traffic in Arms Regulations (ITAR) and Export Control policies can be maintained.

Question 1c:

Will NASA be devoting resources in FY 2020 to developing a LEU reactor for power and if so, how much?

Answer 1c:

NASA will continue to explore both HEU and LEU space reactors in FY 2020. Utilizing FY 2019 funds, NASA will continue NTP fuel development targeting a LEU-fuel solution. This includes complementary efforts under other NASA Programs such as Small Business Innovation Research (SBIR), Space Technology Research Grants (STRG), and Center Innovation Fund (CIF). Some of this research could be applicable to power reactors, and opportunities for cross-platform collaboration will be pursued.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:
Administrator Bridenstine
Submitted by Congressman Crist

Question 1:

Can you comment on how you see CASIS, as the ISS National Laboratory organization, being utilized in the development and execution of the Commercial LEO Development program?

Answer 1:

The ISS National Lab, managed by CASIS, has been a key enabler of the expanded commercial use of LEO for research and technology development by private industry and other Government agencies. The ISS National Lab is currently opening up the possibilities of the Station research environment to a diverse range of researchers, entrepreneurs, and innovators that could create entirely new markets in space. These areas include, but are not limited to, drug delivery systems, crop science, regenerative medicine, reaction chemistry, materials science, fluid dynamics and transport phenomena, on-orbit production and microgravity-enabled materials, protein crystal growth (also known as macromolecular crystal growth), Earth observation, and remote sensing. The ISS National Lab portfolio's current positioning forecasts growth in the next ten years in areas such as cell and gene therapy, 3D bio-printing scaffolds, and aerospace projects using the LEO platform to raise technological readiness levels of next-generation LEO and beyond infrastructure systems. The ISS National Laboratory is helping to establish and demonstrate the market for research, technology demonstration, and other activities in LEO beyond the requirements of NASA.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Casten

Question 1-1a:

The FY 2020 budget request proposed canceling CLARREO Pathfinder. In response to a question by Representative Casten during the hearing, you said that "we have other instruments in orbit right now that are measuring the radiation budget of the Earth," referring to the types of measurements that CLARREO Pathfinder would enable.

As Representative Casten requested in the hearing, please provide a list of the specific operating or planned missions/instruments that would sufficiently meet the high-priority scientific objectives that an eventual CLARREO mission, enabled by the Pathfinder technology demonstration, would address.

Answer 1-1a:

CLARREO-Pathfinder is a one-year technology demonstration consisting of a reflected solar spectrometer instrument that would be flown on the International Space Station. It has two objectives:

1. Demonstrate the ability to conduct on-orbit calibration, to internationally-recognized measurement standards, with higher accuracy than is possible on current on-orbit Earth observing sensors; and
2. Demonstrate the ability to use that improved measurement accuracy to serve as an in-orbit reference for inter-calibration of other key satellite sensors across the reflected solar spectrum.

Several instruments set to operate in the timeframe of CLARREO-Pathfinder will obtain data on the Earth's radiation budget that are similar to those that would be collected by CLARREO-Pathfinder. However, they will do so with lower absolute accuracy than CLARREO-Pathfinder is being designed to achieve. The second objective is a unique feature of this mission, and will enable the transfer of CLARREO-Pathfinder's accuracy standards to other missions, in particular those with the Clouds and the Earth's Radiant Energy System (CERES) and Visible Infrared Imaging Radiometer Suite (VIIRS) instruments, on the Suomi-NPP and Joint Polar Satellite System missions. No current or planned instruments have the cross-calibration capabilities of the CLARREO-Pathfinder mission.

Question 1b:

As Representative Casten requested in the hearing, please "provide specifically who in the scientific community has confirmed that cutting those missions will not interfere with our ability to understand how our climate is changing [and] what we need to do to adapt."

Answer 1b:

We do not have knowledge of who made these specific comments. Several instruments set to operate in the timeframe of CLARREO-Pathfinder will obtain data on the Earth's radiation budget that are similar to those that would be collected by CLARREO-Pathfinder. However, the similar instruments will do so with lower absolute accuracy than CLARREO-Pathfinder is being designed to achieve. Additionally, the CLARREO-Pathfinder was designed as a one-year technology demonstration and was not intended to serve as a long-term climate mission.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:

Administrator Bridenstine

Submitted by Congresswoman Wexton

Question 1:

When discussing the cuts to the NASA Office of STEM Engagement, Administrator Bridenstine repeatedly justified the cuts due to NASA choosing to focus on "areas that have higher return for agency and the country." What specific factors went in to the Administrator's determination to reduce the funding to $0 for the NASA Office of STEM Engagement? Did the Administrator consult with any outside groups or organizations? If so, who?

Answer 1:

NASA has a long history of engaging students in its mission through effective Science, Technology, Engineering, and Math (STEM) engagement activities and programs. NASA's endeavors in STEM engagement began early on, driven by the language in Section 203 (a) (3) of the Space Act which directs NASA "to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof, and to enhance public understanding of, and participation in, the Nation's space program in accordance with the NASA Strategic Plan."

While the FY 2020 budget proposes to eliminate the Office of STEM Engagement (OSE), it is important to understand that STEM education and outreach efforts have always occurred beyond the walls of the Education Office. These include internships managed by our Mission Directorates, our Speaker's Bureau which sends NASA scientists and engineers to meet with educational and civic organizations, and NASA employees who are authorized to use work hours to mentor local students in STEM activities. These are just a few of the STEM activities that NASA employees across the Agency proactively engage on every day. Therefore, even if OSE is eliminated, 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.

Following the elimination of OSE, NASA would staff a small, focused functional office at NASA Headquarters to be accountable for the strategic direction and

coordination of the cross-Agency STEM engagement efforts, including more closely aligning Agency STEM efforts with our Mission Directorates and their missions. This would serve to better inspire students by having them work on real-world missions and problems, which in turn directly impacts NASA missions.

Fully recognizing the importance of its STEM mission, NASA has spent the last two years analyzing ways to optimize Agency STEM efforts as a whole. For example, NASA recently completed a deep-dive assessment of the Agency's Education and Outreach efforts, known as a Business Services Assessment (BSA). During this assessment, a core team collected data from across NASA, conducted surveys and interviews with internal and external stakeholders, benchmarked external organizations, and performed a detailed assessment of existing Education and outreach efforts. Based on this analysis, NASA created a more seamless approach to eliminate redundant functions and duplication of efforts, and fill in existing gaps in order to better serve the STEM engagement community. It also established the STEM Engagement Council (SEC), which is the Agency's governance body accountable for NASA's comprehensive set of STEM engagement functions and activities. Building on the BSA work, OSE is currently undergoing a Mission Support Future Architecture Program (MAP) Project to realign the mission support structures to improve efficiency in order to implement an integrated STEM function with a unified approach that will provide a higher return for NASA missions and the Nation's future STEM workforce.

As further proof of NASA's dedication to STEM outreach, it is important to note that NASA Administrator Bridenstine recently established the NASA Advisory Council STEM Engagement Committee in order to provide external advice and make recommendations regarding NASA's important role of inspiring the next generation. Committee Members represent external STEM stakeholders such U.S. universities and museums and industry associations. NASA is also actively supporting the National Science and Technology Council's Committee on STEM Education endeavors, with Administrator Bridenstine serving as the Committee's Co-Chair. The Committee's recent report, *Charting a Course for Success: America's Strategy for STEM Education*, lays out the federal Government's role in furthering STEM education by working with state, local, education, and American employer stakeholders to build a STEM-proficient citizenry, create a STEM-ready workforce, and remove barriers to STEM careers, especially for women and underrepresented groups.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Babin

General

Question 1:

The NASA IG recently issued a report on NASA's cleanup efforts at the Santa Susana Field Laboratory. The IG questioned "the reasonableness and feasibility of the Agency's current agreement to clean the soil to a Background level." The IG stated, "This cleanup approach is not based on risks to human health and the environment or the expected future use of the land-the standard practice for environmental remediation at similar sites. Further, a soil cleanup to the current levels set by the State of California is expected to cost NASA more than a half billion dollars, take as long as 25 years to complete, and significantly damage flora and fauna at the site. In contrast, soil cleanup to the Recreational level-the standard more in line with the expected future use of the land-would cost about $124M and take approximately 4 years to complete. As such, we question a total of $377M in unfunded environmental liability costs associated with NASA's current SSFL soil cleanup plans as funds that could be put to better use." Is NASA still pursuing a plan that is likely not achievable, would cost more money, take more time, result in no appreciable environmental benefit, and potentially be harmful to animals and plants currently at the site?

Answer 1:

NASA concurred with the recommendations of the March 19, 2019, report of the NASA Office of Inspector General (OIG) on NASA's Progress in Environmental Remediation Activities at the Santa Susana Field Laboratory (SSFL). The OIG recommended that NASA pursue all available options for ensuring a soil cleanup that is "performed in an environmentally and financially responsible manner based on the future use of the property."

In 2017, the California Department of Toxic Substances Control (DTSC) released a draft Programmatic Environmental Impact Report (PEIR) that described significant and unavoidable impacts associated with soil cleanup at SSFL. The cleanup outlined in DTSC's draft PEIR requires substantially greater soil removal than original estimates and would pose significant environmental impacts to the site's valuable and protected natural, cultural and biological

resources. NASA has expressed these concerns to DTSC.

NASA entered into the 2010 Agreement on Consent (AOC) with the California DTSC in good faith, with the expectation that the State would use sound regulatory discretion in calculating soil cleanup levels for the site that would be both fully protective of public health, and practically and technically achievable. NASA encourages the DTSC to reconsider the limited alternatives included in its PEIR and expand its analysis and evaluation of clean-up actions to include options that would be less harmful to the site, preserve its unique resources, and still fully protect public health.

On April 5, 2019, NASA announced its decision to prepare a Supplemental Environmental Impact Statement (SEIS) for soil cleanup at the NASA portion of SSFL. Due to significant changes in soil cleanup estimates since NASA's 2014 EIS, as well as additional new data provided by the best science and technology available, NASA has determined that the SEIS is necessary in order to maintain compliance with the National Environmental Policy Act of 1970. From this further examination, NASA will assess updated soil and environmental data to refine and inform decision-makers, the regulating agencies, and the public about the likely environmental impacts that the cleanup will have on the community as well as the natural, cultural and biological resources at SSFL.

NASA remains firmly committed to a cleanup that is fully protective of public health and the environment. The Agency will continue to work with the DTSC and all interested stakeholders to implement a cleanup that is technically achievable, based on the best available science, protective of the surrounding community and the important natural and cultural resources at SSFL.

Human Exploration and Operations

Question 2:

What kind of capabilities will the Lunar Gateway demonstrate? How will those new capabilities enable expansion of human and robotic presence throughout the solar system?

Answer 2:

The lunar Gateway is being designed to support the return of American astronauts to the surface of the Moon. The architecture to enable the Exploration Campaign and support a human landing on the Moon in 2024 (which includes the Gateway as well as the Orion crew vehicle and Space Launch System [SLS]) is the same architecture already in development to support our previous goal to land on the Moon in 2028.

The Gateway will be a spacecraft assembled in cislunar space that will be used as a staging point for missions to the lunar surface and to future deep space destinations. The Gateway will function as a mobile base camp from which NASA, its international partners, and its commercial partners, can mount sustainable robotic and human expeditions to and around the Moon. Our initial focus must be on speed, but

long-term sustainability and broader partnerships will be required to support our ultimate goal: human missions to Mars.

NASA and its partners will develop and deploy the Gateway's two initial components: the Power and Propulsion Element (PPE) that will launch in 2022 as a public-private partnership, and a minimum Habitation capability that will launch in 2023. Both of these modules will be launched on commercial launch vehicles. This initial Gateway configuration can support the first, short-duration missions to the lunar surface. For the 2024 mission, Gateway will serve as the staging point for the three elements of the human lunar landing system (a transfer vehicle, descent vehicle, and ascent vehicle) launched by commercial vehicles, and the crew that will arrive on Orion.

NASA will build on the 2024 mission to ensure that access to the Moon and its resources is sustainable over the long haul. This will require NASA to expand its capabilities with international and commercial partners with the goal of improving the sustainability and cost-effectiveness of lunar activities. The Gateway has several attributes that will contribute to long-term lunar exploration: it will be sustainable (e.g., through resupply and the ability to conduct long-duration human surface missions and extended uncrewed operations); reusable (unlike the Apollo Command/Service Module, Gateway will be on hand to support many lunar missions); and flexible (using its solar-electric PPE, Gateway will allow us to access more regions of the Moon than ever before). Gateway will be followed by other assets that would enable sustainability, such as reusable landers, reusable tugs, rovers, robotics, etc., allowing our astronauts to operate on the Moon for extended durations and to take advantage of the Moon as an analogue for Mars. In a Near-Rectilinear Halo Orbit around the Moon, Gateway will support communications with the Earth, have the ability to abort from the surface of the Moon to the Gateway, and experience benign thermal effects. Gateway can also provide additional capabilities that could enable science utilization, exploration technology demonstrations, and potential commercial utilization. Ultimately, Gateway enables the demonstration of capabilities on and around the Moon (such as extended surface operations; high-power solar-electric propulsion systems; human health and life support systems technologies; radiation mitigations for both crews and hardware; and deep-space rendezvous, proximity operations, and navigation) that are required for human missions to Mars and other destinations.

Question 3:

How do multiple launches or multiple stages affect safety and risk postures for lunar landers?

Answer 3:

NASA is planning to maximize reusability in its deep space exploration systems, including human lunar landers, and will work to ensure the safety of the astronaut crews. NASA is soliciting lunar lander architecture through a Broad Agency Announcement (BAA) under its second Next Space Technologies for Exploration Partnerships (NextSTEP-2) effort. The NextSTEP-2 BAA is soliciting concepts from

U.S. industry in support of rapid development, integration, and crewed demonstration of the lander elements as a functional human landing system that can accelerate landing on the Moon in 2024.

These inputs, in turn, will inform NASA's plans that currently include a transfer vehicle ferrying a two-stage lunar lander from the Gateway to low lunar orbit, whereupon the lander would descend to the lunar surface. Under this notional plan, at the conclusion of the surface expedition, an ascent stage would carry the crew back to low lunar orbit, where they would rendezvous and dock with the transfer vehicle and proceed back to the Gateway. Both the transfer vehicle and ascent stage would be refueled at the Gateway and prepared for future lunar missions. This system would allow for mission aborts at various points during the lunar sortie using the transfer vehicle or the ascent stage of the lander. If required, the ascent stage could even return to the Gateway without the need to dock to the transfer vehicle.

The overall safety and risk posture of a mission as complex as a human lunar landing is dependent on a number of interrelated factors, starting with the overall design of the individual hardware elements (which are themselves highly complex systems), test and evaluation plans, the concept for how the systems will be operated, system and architectural redundancy and reliability, launch vehicle availability, mission abort and other contingency options (which change throughout the mission), astronaut and operator training, and a wide variety of other technical and operational factors. Increasing the number of architectural elements, such as adding multiple launches or stages, can introduce risks. On the other hand, devolving the lunar lander mission into a series of lander and transfer elements, each optimized for their specific function, aggregated at and staged out of a reusable Gateway platform, and leveraging reusability, creates significant opportunities for reducing risks and improving overall mission safety and success. Lunar lander elements can be tested and checked out *en route* to the Gateway. Astronauts arriving at Gateway in Orion can check out lunar lander systems at the Gateway before departure to the lunar surface. Staging lunar lander elements creates safe abort opportunities for the crews to return to Gateway if necessary. Reusability allows us to observe the reliability of systems over time, allowing for continuous improvement of the overall architecture and informing the design of the high-reliability systems needed for sustained missions at the Moon and in preparation for long-duration missions to Mars.

Question 4:

How long will the Lunar Gateway operate?

Answer 4:

The Gateway is being designed for an operational life of at least 15 years.

Question 5:

When will NASA issue a contract for the second Launch Platform that was funded last year? Does NASA need more money to complete this project? If so, how much more? Does this budget request assume funding to complete theproject?

Answer 5:

Consistent with provisions in the FY 2018 Consolidated Appropriations Act (P.L. 115-141), as well as the NASA Administrative Provision in P.L. 115-141 pertaining to the Agency's Operating Plan, NASA is proceeding with a contract award in 2019 to start building the second mobile launcher platform.

Although NASA began design and construction on the second mobile launcher platform, additional funding to complete the project is being deferred. NASA does not have plans to utilize the second mobile launcher in the near term and a final Block 1B design has not been set. NASA is deferring these activities until needed but allowing core design and construction of the platform to continue while awaiting a decision on the upper stage configuration for future missions.

Question 6:

Once the Commercial Crew program is fully underway, NASA will have the ability to add an additional crewmember to the International Space Station. How will this influence planning for ISS transition in the next decade? Could the ISS support more than seven crew?

Answer 6:

U.S. commercial crew capabilities will enable the Station crew to be expanded from six to seven astronauts and cosmonauts, resulting in a doubling of on-orbit research time to almost 80 hours per week. This is because the seventh crew member will be able to focus his or her time almost exclusively on conducting experiments, rather than on Station operations and maintenance. While Station has hosted up to 13 crew at a time during brief periods when the Space Shuttle was docked to the Station, it is important to note that the long-term crew complement is constrained by the number of seats available on the crew transport vehicles docked to ISS. Once commercial crew vehicles have become operational, the ISS could support four additional crew members for four weeks nominally beyond the seven ISS crew members. It is possible to either increase the number of crew members by a couple for a short period, or extend the duration of the four additional crew members with additional logistics.

Question 7:

Please discuss NASA's current thinking on commercialization and transition strategies for the ISS.

Answer 7:

NASA's current thinking on commercialization and transition strategies is covered in the International Space Station Transition Report directed in the NASA Transition Authorization Act of 2017 (P.L. 115-10) and delivered to Congress in March 2018. The report may be accessed via the

link below:

https://www.nasa.gov/sites/default/files/atoms/files/iss_transition_report_180330.pdf

Question 8:

If NASA is unable to reduce its costs for operations and transportation to the ISS by 2025, and if the LEO commercialization activity does not bear fruit, what should the US do regarding its presence on the ISS at that point? Should we defer Lunar exploration to maintain a presence in low Earth orbit? If so, for how long?

Answer 8:

ISS is a critical component of the National Space Exploration Campaign, and NASA will continue its mission in LEO with the ISS to enable exploration with humans to the Moon and on to Mars, continuing to perform research that benefits humanity, supporting National Lab research by private industry and other organizations, and working towards reducing operations and maintenance costs. The Commercial LEO Development effort is providing resources for NASA to assist industry in developing a commercial LEO presence, with and without crews. As those commercial LEO destinations are available, and without a gap in human presence in LEO, NASA intends to implement an orderly transition from current ISS operations to the new commercial enterprise as laid out in NASA's ISS Transition Report. NASA has also identified its long-term requirements for LEO operations and research that is planned to be conducted on the ISS and transitioned to a commercially operated platform(s). NASA has every reason to believe that both its Commercial LEO Development and lunar exploration efforts will be successful, and is not currently evaluating any trades specifically between these two lines of effort.

Question 9:

We are starting to see an increasing convergence between human space exploration and the planetary science activities carried out under the Science Mission Directorate. Could you please talk a bit about this convergence and how the two lines of effort can be more effectively coordinated?

Answer 9:

The convergence between human spaceflight exploration and planetary science activities is deliberate. The two share common goals and objectives in exploring the Moon and Mars. Finding and establishing ground truth of volatiles, such as water-ice, is an example of this. Water-ice may provide the critical resource needed to sustain human life on the surface of the Moon, while also providing fuel for future rockets and landers. Determining the distribution of the water-ice in the permanently shadowed regions also aligns with Decadal Survey science objectives.

To ensure the close coordination between the human spaceflight exploration and

science objectives, and proper alignment of technology development efforts to support both, NASA established an Office for Exploration in the Science Mission Directorate that is led by a new Deputy Associate Administrator (DAA) for Exploration. The responsibility of the DAA for Exploration is to ensure and facilitate the integration of the human exploration, science, and technology development efforts to better support and enable the Agency's Exploration Campaign objectives. Since the establishment of the DAA for Exploration, there have been ongoing integrations efforts with senior leadership in the Human Exploration and Operations Mission Directorate (HEOMD) and the Space Technology Mission Directorate (STMD). Examples of successful integration efforts include the consolidated exploration budget request in the FY 2020 President's Budget Request, the ongoing participation of the three mission directorates in dialogue related to the Gateway platform, and robotic and human lunar surface exploration goals and objectives.

As the critical elements of NASA's Exploration Campaign continue to mature, undergo development and are deployed, the integration between the HEOMD, SMD and STMD will continue to evolve as needed to ensure close coordination and integration.

Question 10:

Congress has consistently appropriated more funding than requested in the Presidential Budget Requests each year for the past six years to ensure Orion remains on schedule. Congress has maintained its support for keeping Orion on schedule. In the FY 2020 PBR, NASA once again requested less than FY 2019 appropriations. Will a decrease in funds still maintain the current Exploration Mission I and 2 schedules?

Answer 10:

The FY 2020 Budget, as amended, requests $1,406.7 million for Orion, $56.7 million above the FY 2019 level. NASA is committed to flying Artemis 1 and Artemis 2 in order to ensure the safe landing of a crew (including the first woman) on the Moon by 2024. This focus is reflected in the Agency's amended FY 2020 budget submit to Congress.

Question 11:

What is NASA's plan for ISS operations after 2024? How will this impact Deep Space Exploration efforts, assuming that NASA only sees flat or moderate increases in future budgets?

Answer 11:

NASA will continue research and technology efforts in low-Earth orbit (LEO) using the International Space Station (ISS) to enable exploration with humans to the Moon and on to Mars. NASA is working to implement a step-wise transition of ISS from the current regime of NASA sponsorship and direct NASA funding, to a regime

where NASA is one of many customers purchasing services from a LEO non-Governmental human space flight enterprise. NASA will gradually transition from current ISS operations to this new regime to ensure that the United States always has access to a crewed space station in LEO. As part of this transition, NASA plans to purchase needed LEO services from a commercial operator of ISS and/or new commercial LEO destinations. The full transition from ISS to new commercial LEO destinations will be gradual.

Over the next several years, the research program will continue to focus on capabilities needed to maintain a healthy and productive crew in deep space. Manifested or planned experiments and demonstrations to enable human exploration at the Gateway, lunar surface and into deep space include tests of improved long-duration life support, advanced fire safety equipment, on-board environmental monitors, techniques to improve logistics efficiency, in-space additive manufacturing, advanced exercise and medical equipment, radiation monitoring and shielding, human-robotic operations, and autonomous crew operations.

Science

Question 12:

This budget request for science is $677M more than what the Obama Administration planned for FY 2020 in its FY 20I7 request. How does this increase in science funding enable future scientific discoveries?
Answer 12:

Compared to the notional out-years of the FY 2017 request, the FY 2020 request includes increases to Planetary Science programs and projects, including:

- the Lunar Discovery and Exploration Program
- Europa Clipper
- the Planetary Defense program and its Double Asteroid Redirection Test (DART) mission
- the competed Discovery and New Frontiers programs
- planning for a Mars Sample Return mission

These increases address priorities of the most recent National Academies Decadal Survey for Planetary Science. The Lunar Discovery and Exploration Program is also critical for returning humans to the Moon by 2024.

Question 13:

NASA has historically developed first-of-a-kind earth science instruments that, once proven, are transferred to operational agencies like NOAA or USGS. This budget requests seems to depart from that long-standing philosophy by funding the procurement of long-term data-sets that were previously NOAA requirements. It also funds missions not recommended by the decadal survey, instruments that collect data similar

to existing international or other agency missions, and a mission that was criticized by the NASA IG as being unnecessary. How does NASA plan to prevent these legacy missions from delaying or inhibiting the development of next generation technologies?

Answer 13:

The scope and content of the FY 2020 budget request is consistent with previous requests. It does not include any new Earth Science missions or projects, except those that are recommended by the 2007 or 2017 Earth Science and Applications from Space Decadal Surveys or selected through competitive solicitations (e.g., Earth Venture missions).

The 2017 Decadal Survey states that NASA should implement the current Program of Record, which refers to the missions already in development that are largely based on the recommendations from the 2007 Decadal Survey. Completion of the Program of Record is a fundamental assumption of the 2017 Decadal Survey; for example, the 2017 Decadal Survey stated:

> *Recommendation 3.2: NASA should implement a set of space-based observation capabilities based on this report's proposed program (which was designed to be affordable, comprehensive, robust, and balanced) by implementing its portion of the Program of Record and adding observations described in Table 3.3, "Observing System Priorities."*

Completing the current Program of Record by 2023 is an essential foundation to allow NASA to proceed with the development of the next generation of Earth Science projects.

Question 14:

In 2005, the Near-Earth Object Survey program was created to detect near-Earth objects (NEOs) greater than 140 meters in diameter within 15 years (specified in law). NASA has only found about 43 percent of these NEOs. However, the space-based telescope Near-Earth Object Camera (NEOCam) mission, or a similar concept, could discover and characterize most of the potentially hazardous asteroids that are near the Earth. How does NASA propose funding the NEOCam mission in FY 2020? Has it been selected to proceed to mission formulation? If not, how is NASA planning to meet the survey requirement in law? Are there other spacecraft proposals that could accomplish the same goal?

Answer 14:

NASA Science Mission Directorate (SMD), through the Planetary Defense Program, has proposed to continue development of a space-based infrared instrument at approximately $36 million in the President's

FY 2020 budget request.

Current assets with the addition of the NSF's Large Synoptic Survey Telescope (LSST) in 2023 are projected to meet the George E. Brown survey goal of detecting 90 percent of NEOs greater than 140 meters in the 2040s. Additional assets (both ground- and space-based) would be required to significantly reduce the time necessary to detect and characterize NEOs greater than 140 meters in size.

Pursuant to Section 511 of the NASA Transition Authorization Act of 2017 (P.L. 115-10), NASA will continue to provide status reports to the Congress on NEO detection and characterization.

Question 15:

The President's FY 2020 budget request directs NASA to continue to utilize CubeSats and private sector remote sensing payloads. How can NASA leverage Earth Science funding more effectively? Is this kind of "commercial off the shelf' technology development important in NASA's overall mission?

Answer 15:

Investment in CubeSats technologies and leveraging commercial capabilities are indeed important to NASA. Through the In-Space Validation of Earth Science Technologies (InVEST) program, NASA's Earth Science Division continues to develop new CubeSat technologies both within NASA and in the non-governmental sector. CubeSats can now also be selected as science payloads under Earth Venture Instrument competitive solicitations. As a part of the Earth Venture Instrument program, NASA selected the CubeSat missions TROPICS and PREFIRE in 2016 and 2018, respectively.

NASA is also pursuing the hosting of payloads on commercial satellites. In September 2018, General Atomics was awarded a contract to host the Multi-Angle Imager for Aerosols (MAIA). This is the first hosted payload for NASA Earth Science.

NASA continues to explore commercial sector developments in remote sensing payloads, especially where measurements and data are complementary to meeting NASA's Earth Systems science and applications goals. In September 2018, NASA launched a pilot program to evaluate whether Earth science data from commercial small-satellite constellations could be utilized to augment observations from the Agency's fleet of orbiting Earth science missions. The Agency awarded sole-source contracts to acquire data products from three private sector organizations: DigitalGlobe, Planet, and Spire. Even in cases where commercial data are not initially suitable for science purposes, there can still be synergies for collaboration.

Question 16:

Mars 2020, our next flagship mission to Mars, will use technology from the Curiosity rover to mitigate cost and risk. An OIG report from last year noted that several new technologies were still facing high risks, and NASA recently indicated the program could breach its cost estimate. What is NASA doing to address these remaining risks? If NASA terminates some of the instruments, will the mission still be able to generate new and novel scientific data?

Answer 16:

At this time, the Mars 2020 project has retired or mitigated all of the new technology risks identified by the recent OIG report. For example, the flight units for the sampling and caching robotic arms have been completed and delivered to JPL and components of the Adaptive Caching Assembly are being integrated and tested, such that the Sampling and Caching System (the main technology risk reported by the OIG) is on schedule for delivery by late summer. The MOXIE instrument has been completed and installed into the rover chassis. In addition, the MEDA instrument and SuperCam calibration target, which were noted as foreign partner contributions of concern, have been completed and delivered to JPL. Currently, no science instruments are being considered for termination, as all are on track for delivery in time for the spacecraft need dates.

Question 17:

When it comes to developing and conducting a mission like a Europa Clipper, does more funding mean faster development and launch? Or are there elements that cannot be sped up even with additional funding?

Answer 17:

The scientific and engineering elements of the Europa Clipper mission, designed to investigate whether this moon could be an abode for life, are complex and require the multi-faceted expertise of an extensive team, thus, the timetable is not solely dependent on funding or launch capabilities. Multiple elements of the project must be developed serially and therefore, cannot be sped up even with additional funding. Recent assessments by NASA and the Europa Clipper project team have concluded that a launch readiness date of 2023 is the most feasible option and the President's FY 2020 budget request supports such a schedule.

Question 18:

The budget proposal does not include funding for the Europa lander. Why was this program cancelled?

Answer 18:

The FY 2020 President's budget request for NASA does not include

funds for a $3.5 – 5.0 billion Europa Lander due to support of higher Agency priorities. This is consistent with previous year budget requests. This also is consistent with the National Academies of Sciences, Engineering, and Medicine (NASEM) Planetary Science Decadal Survey midterm assessment that was the product of a committee of experts from the planetary science community. The midterm assessment recommended that the Europa Lander mission be assessed in the context of other planetary priorities in the next decadal survey.

Question 19:

The budget request proposes launching the Europa Clipper on a commercial launch vehicle, despite appropriations law that requires the mission be launched on an SLS to decrease the transit time and maximize the science conducted around Europa. How will the mission's science be impacted by this decision?

Answer 19:

NASA will follow the law regarding launch of the Europa Clipper mission. The FY 2020 President's budget request for NASA proposes to launch Europa Clipper in 2023 on a commercially-procured launch vehicle. Following an analysis of availability of launch hardware and facilities, overall launch manifest optimization, and cost, the Administration believes it would be more appropriate for the Europa Clipper to utilize a commercially-procured launch vehicle instead of a Space Launch System (SLS) variant. Science quality is not impacted by this decision. Delivery of scientific data to the planetary science community will be delayed, but is not in any way decreased, due to this trade-off involving cost.

Additionally, the Administration is concerned that the mandate to use an SLS rocket for the Clipper will slow the lunar exploration program, which requires every SLS rocket available. NASA does not believe that it can produce enough SLS rockets to do both Europa and the Artemis missions in the timeframe laid out. Unlike the human exploration program, which requires use of the SLS, the Europa mission could be launched by a commercial rocket.

Question 20:

The previous decadal survey for planetary science listed both the Europa mission and a Mars Sample Return mission as high priorities. In order to execute both at the same time, those concepts were scaled back to proposals that are more reasonable: the Europa Clipper and the Mars 2020 Rover. This budget request proposes a new Mars Sample Return Mission in addition to the Mars 2020 Rover. What impact will that have on other planetary missions, or the science division as a whole? What principles will inform the trades that NASA will make?

Answer 20:

The President's FY 2020 budget request proposes initiating a Mars Sample Return (MSR) mission – which is the next step towards accomplishing the goals outlined in the current decadal survey for planetary science, "Vision and Voyages for Planetary Science in the Decade 2013-2022 (2011)." The Mars 2020 mission fulfills the highest-priority large mission recommended by the decadal survey: a mission to select and cache samples of Martian rock and soil that begins a multiple-mission MSR campaign extending into the decade beyond 2022. The mission concept was reduced in cost and risk by descoping the proposed landed system from two rovers down to a single rover based upon the design of the successful Mars Science Laboratory (MSL). The resulting Mars 2020 rover will have significant scientific return in addition to being the first step in a sample return campaign. The requested budget also proposes initiating a cooperative partnership with the European Space Agency to conduct the campaign of sample retrieval missions, as envisioned by the Decadal Survey. This partnership will enable NASA to achieve the objectives of MSR at reduced cost and risk.

The Europa Clipper mission fulfills the decadal survey's second priority large mission. The cost was brought within budgeting constraints by streamlining the mission and changing the spacecraft's trajectory from an orbit around Europa to a series of flybys.

Through Congress' appropriations and NASA's innovation efforts, the decadal survey's first and second major mission priorities will both be accomplished. The MSR campaign fits within the proposed Mars Exploration Program budget and preserves the rest of the planetary portfolio and priorities of the Decadal Survey.

Question 21:

The recent Earth Science decadal review mentioned the value of CubeSats, smallsats, and hosted payloads. Given the proliferation of CubeSats and private sector remote sensing payloads, how can NASA leverage Earth Science funding more effectively? Is this kind of technology development important in NASA's overall mission?

Answer 21:

CubeSats, smallsats, and hosted payloads are indeed important to NASA, including the Earth Science Division (ESD). NASA's investments in and partnerships using these approaches have demonstrated the value of deploying small-scale, cost-efficient observing platforms to gather Earth observations from a greater variety of on-orbit sources. Because they draw heavily on commercial capabilities and partnerships, these technologies align with NASA's objective to advance our science and discovery through engagement with external partners.

Among the objectives of ESD's Earth System Science Pathfinder (ESSP) program is the pursuit of innovative approaches for addressing Earth science research by embracing small satellite projects and providing periodic opportunities to accommodate new and innovative techniques to address scientific priorities. For example, CYGNSS is an eight-satellite smallsat constellation that measures ocean

surface winds at the core of tropical cyclones, and has been operational since 2016. This project is providing innovative science at a relatively low cost, demonstrating a new measurement technique for future science missions. In addition, ESD recently selected two CubeSat constellation projects - TROPICS and PREFIRE – from an Earth Venture Instrument (EVI) solicitation within ESSP in order to address science related to tropical cyclone thermodynamics and Arctic radiative energy, respectively. These low-cost missions seek to address important NASA science.

The Earth Science Technology Office (ESTO) invests in the development of new CubeSat technologies within NASA and in the non-governmental sector through the In-Space Validation of Earth Science Technologies (InVEST) program.

At the same time, NASA aims to promote and harness commercial remote sensing technology when commercial measurements could be complementary to NASA's science and applications goals. In September 2018, ESD launched a pilot program to evaluate how Earth science data from commercial small-satellite constellations could be utilized to augment observations from the Agency's fleet of orbiting Earth science missions. The Agency awarded sole-source contracts to acquire data products from three private sector organizations: DigitalGlobe, Planet, and Spire. Even in cases where commercial data are not initially suitable for science purposes, there can still be synergies for collaboration.

NASA is also pursuing the hosting of payloads on commercial satellites. In September 2018, General Atomics was awarded a contract to host the Multi-Angle Imager for Aerosols (MAIA), which will characterize the sizes, compositions, and quantities of different kinds of particulate matter in air pollution. This is the first hosted payload for NASA Earth Science, with a mission launch expected as early as the fourth quarter of 2021.

These multiple innovative approaches are important to ESD as they provide opportunities to address science priorities at costs lower than traditional satellite projects. While these approaches are not currently capable of fully addressing all of Earth Science's needs, they are making important contributions and are growing capabilities for the future.

Aeronautics

Question 22:

The FY 2020 budget requests to reallocate funding for aeronautics facilities from the Aeronautic Mission Directorate to the Safety, Security, and Mission Services Directorate. In doing so, it appears the budget requests a cut, but in reality, represents a healthy funding profile for Aeronautics. Can you discuss how moving this funding is better for NASA and the aeronautics enterprise?

Answer 22:

NASA's wind tunnels are unique national assets and the Agency is committed to

maintaining, modernizing, and enhancing the Aeronautics Evaluation and Test Capability (AETC). Prior to FY 2017, AETC received a portion of its annual funding directly from the Aeronautics Research Mission Directorate. The rest was expected to be paid for by the users of the wind tunnels. Under this model, the ultimate funding total for AETC each year was unknown. Managers were forced to focus on how to cover their operating expenses for the year, and there was little investment made in enhancing or modernizing the capability. The funding profile increased in FY 2019 and again in FY 2020 to cover consumables (power, liquid nitrogen, etc.). The most consistent user of AETC is the ARMD, but projects in SMD, HEOMD, and STMD all utilize the capability from time to time. To acknowledge the benefits to the entire Agency, the FY 2017 Budget included direct funding in four appropriations accounts.

NASA executed the budget for AETC this way for FY 2017 and FY 2018. However, this model requires us to reconcile estimated funding allocated for AETC to each account with actual data. End-of-year transfers between appropriations ensure accurate accounting. Under the FY 2017 model, such transfers pose an administrative burden to Congress, AETC and the relevant NASA Centers. To reduce this burden and simplify an overly complicated accounting scheme, NASA made the decision to continue to provide the full annual AETC funding level, but to do so from a single source.

The Shared Capabilities and Assets Program (SCAP) in the Safety, Security, and Mission Services account ensures select critical test facilities are operationally ready to meet mission and program requirements from across all of NASA's appropriations by sustaining a skilled workforce and performing essential maintenance. The program already supports essential core technical capabilities: arc jets, simulators, thermal vacuum chambers, and space radiation environments. AETC is a natural fit in this program, and so the Agency decided to consolidate the funding from across the missions into this line.

Question 23:

NASA is working with both tech companies and traditional aerospace firms on technology to enable a future where people and goods can be safely and efficiently transported around densely populated cities aboard air vehicles, called Urban Air Mobility. How is NASA collaborating with industry, academia and the Federal Aviation Administration (FAA) to identify and seek solutions to the challenges unique to this newera in aviation?

Answer 23:

Collaboration with FAA, industry and academia will be critical to the success of NASA's Urban Air Mobility research and development efforts. NASA Aeronautics has conducted research in the technology arenas of unmanned aircraft systems (UAS) and UAS traffic management (UTM) for the past decade, in close coordination with industry and the FAA. Many of the technical challenges addressed in this research will have direct applicability to future requirements and challenges of Urban Air Mobility (UAM) including vehicle technologies such as Detect and Avoid and secure

command and control communications, as well as the UTM operational construct itself which is likely to be a critical enabler of a safe and scalable workable UAM system.

NASA is using many complementary venues to engage with the community on UAM. Starting in 2016, NASA conducted public workshops and sponsored market studies related to On Demand Mobility, building a community dialogue around UAM challenges and opportunities. NASA leadership and subject matter experts similarly engaged in discussions with FAA counterparts to identify community needs and FAA requirements that would inform NASA research. NASA Aeronautics reconstituted in 2018 the Aeronautics Research and Technology Roundtable (ARTR) under the auspices of the National Academies of Sciences with an enhanced focus on UAM as another important source of input from traditional and non-traditional industry members, academia and the FAA.

As a result of this broad community engagement, NASA is planning series of Grand Challenge demonstrations wherein industry will demonstrate vehicle and operational solutions for UAM ecosystem-wide, system level safety through increasingly more difficult integration scenarios. Participants will demonstrate practical and scalable system concepts while building a technical knowledge base used to inform and meet requirements and standards for both vehicles and air traffic management systems. NASA sponsored an Industry Day in late 2018 and issued a Request for Information to bring the stakeholder community together to solicit feedback on the Grand Challenge concept and assess industry interest in participation. Initial feedback has been positive, and NASA is refining plans based on the results.

Through the Grand Challenge and other engagements with the broader UAM ecosystem members, NASA will identify critical barriers to overcome through future R&D, vehicle and air traffic management system architecture, technologies, system integration and certification.

Question 24:

NASA's Aeronautics program works closely with industry to advance the state of the art in aviation technology. Which aviation technologies should NASA investigate in cooperation with industry for the national interest, and which technologies should industry be pursuing on its own?

Answer 24:

The critical challenge—and opportunity—facing the United States is to remain at the forefront of a growing and evolving aviation market. We must maintain leadership through technological superiority, and NASA Aeronautics has a unique and important role in that formula. NASA Aeronautics will continue its role of supporting a long-term vision for aviation and undertaking pre-competitive research and development that falls outside the scale, risk, and payback criteria that govern commercial investments. Engagement with industry during formulation and execution of NASA's research activities helps NASA to better understand industry priorities and capabilities, and supports the eventual transition of research results to

the community. Once NASA explores and demonstrates the feasibility of these high risk, high payoff technologies and concepts, U.S. industry can then further mature them and transition them to commercial products. Companies also pay to use NASA ground and flight test infrastructure to validate their concepts and technologies, or to collaboratively explore new innovations for flight.

Similarly, NASA's research provides validated findings that inform the Federal Aviation Administration's (FAA) policy and rulemaking processes, industry standards, and global aviation standards and recommended practices. For example, NASA research into new air traffic management concepts and technologies directly transitions into FAA upgrades to the Nation's air traffic management system. NASA also conducts research into recognition and timely mitigation of safety issues as they emerge, before they become hazards or lead to accidents.

In terms of specific technology areas, NASA is conducting research in collaboration with industry to address the most critical long-term challenges facing aviation across six strategic research thrusts, focused on areas with the greatest community impact. NASA is building the quiet supersonic X-59 aircraft to collect community response data, enabling new rules to open up the market for overland commercial supersonic flight so companies can invest in developing and producing new aircraft for this market. NASA also is collaborating with U.S. industry to investigate innovative technology for subsonic aircraft such as advanced configurations and wing design, transformative structures, propulsion-airframe integration, and small-core turbine engines. NASA is conducting research to make design and manufacturing processes more efficient and reduce the time and cost to build aircraft. In FY 2020, NASA will complete the Advanced Composites Project, a six-year focused effort with industry to significantly reduce the time needed to develop and certify new composite structures for aerospace applications.

NASA is leading research into new components, technologies and powertrain architectures for electric or hybrid electric systems that can bring about revolutionary improvements in small and large transport aircraft. NASA's work on the X-57 Maxwell aircraft – an all-electric, general-aviation-size plane – already is delivering to the community important lessons about designing, building and operating an all-electric system. Industry will leverage NASA research to design and develop new vehicles. Building on these activities, NASA will refine concepts and technologies and validate new electric systems through ground and flight tests using the world-leading NASA Electric Aircraft Test Facility (NEAT) capable of conducting full scale ground test of high-power electric propulsion systems.

NASA has been conducting research to inform development of standards supporting safe integration of Unmanned Aerial Vehicles into the National Air Space, as well as new operating concepts such as UAS Traffic Management or UTM. UTM enables widespread low-altitude UAS operations by providing air traffic management services to UAS operators, as an intermediary between the FAA and UAS operators. NASA has collaborated with industry and the FAA to develop and test the UTM system through increasingly complicated flight trials at FAA test sites across the U.S. Industry-led domestic and international standards development organizations and trade groups have established working groups focused on UTM Services and

supporting UAS technologies, and industry is investing in developing vehicles and systems and bringing them to market.

NASA is building on these experiences to enable creation of an urban air mobility or UAM system that is safe, economical and environmentally friendly. NASA is preparing a series of "Grand Challenges" that will provide a means to assess the maturity of key systems for Urban Air Mobility. Through these Grand Challenges, NASA will serve as a catalyst for companies to rapidly develop and demonstrate their capabilities in the U.S. while setting the course for the research, investment and regulations needed to realize the potential of UAM. NASA will identify critical barriers to UAM requiring NASA research such as assured autonomy and safe UAM vehicle operations and develop future research programs accordingly.

NASA continues a stable investment in unique specialized facilities and experts who conduct fundamental research to address key challenges in hypersonic flight, primarily in close coordination with the Department of Defense (DOD), to leverage DOD investment in ground and flight activities.

Space Technology

Question 25:

Restore-L, a proposed satellite-servicing mission, was estimated to cost about $700M dollars. This budget request restructures this effort, focusing instead on pursuing lower-cost ground-based demonstrations to help commercial markets and other government partners. How will NASA ensure that this effort does not duplicate other government efforts or compete with private sector investment?

Answer 25:

NASA sees substantial value in satellite servicing capabilities. However, there are already significant investments from industry and another Government Agency to develop commercial satellite servicing capabilities. Therefore, the Agency has proposed an alternative approach to enable a flight demonstration of satellite servicing technologies by leveraging commercial interests and developing capabilities in a cost-effective manner. In this proposal, NASA would continue development of the critical satellite servicing technologies to Technology Readiness Level (TRL) 6, while pursuing public-private partnerships with industry where commercial partners would propose which technologies in development they would demonstrate on their spacecraft based on their business plans. NASA believes the most cost effective approach is to utilize our technical expertise to develop these key technologies as ground developments, while leveraging the strong commercial interest to enable a flight demonstration through partnerships or Technology Transfer mechanisms. This will provide a clear path to transferring the technologies to industry for multiple applications without being in competition with private industry as well as minimizing duplication of efforts by other Government agencies.

Other

Question 26:

In 2013, this Committee heard testimony that 80 percent of NASA's infrastructure was beyond its constructed design life. Is this still the case? What can we do to ensure a key component of our nation's aerospace infrastructure does not fall into disrepair?

Answer 26:

NASA owns and manages a portfolio of facilities and real property with a total footprint of more than 500 square miles with a current replacement value of approximately $38 billion. Of that value, 80 percent is invested in constructed buildings and structures, predominantly technical in purpose and use. Likewise, as you note, 80 percent of NASA's facilities are more than 40 years old, and some have been in inventory for 80 years. Older facilities are more difficult and costlier to maintain, and are not designed to efficiently support the requirements of today's highly sensitive, technically evolved spacecraft and related hardware and systems. The advanced age of many of NASA's technical facilities also means that, despite ongoing maintenance, there is an intrinsic decline in quality and condition of the facilities, which creates risk to programs and projects that must be managed.

A challenge to managing NASA's highly technical programs is maintaining and modernizing facilities that were designed for an earlier age and purpose. NASA is addressing these challenges with infrastructure renewal policies that are founded on strategic facilities replacement goals for a gradual 25 percent Agency-wide reduction in facilities footprint over 20 years, as obsolete facilities are demolished and replaced with new, flexible-use, energy-efficient, sustainable structures. As these strategies are implemented, NASA continues to contend with the challenge of managing the demands of over $2.3 billion in deferred maintenance requirements. While NASA has made progress in holding steady the rate of increase through aggressive revitalization plans and demolition across its Centers, the ability to effect measurable reversal in the growth of these deferred requirements has remained elusive.

A well-functioning, efficient and cost-effective infrastructure is necessary for the support of NASA's mission requirements, and has a direct bearing on the level of risk to NASA mission objectives that must be managed. The availability of sufficient resources for NASA to meet these challenges of sustaining its infrastructure remains more critical than ever. NASA's FY 2020 budget request includes critical funding for construction and environmental projects to address these significant challenges. This funding will be important to enable NASA Centers to undertake actions that carry the Agency forward toward its infrastructure management objectives, including replacing obsolete capabilities with facilities that meet the demands of the missions of tomorrow.

Question 27:

NASA is the home to our nation's best and brightest minds. Does NASA see a need to change any of its employment policies? Are we prepared to maintain a vibrant and productive NASA workforce in the near- and long-term? Are there new, innovative, or even radical approaches to addressing this issue that should be more widely discussed?

Answer 27:

Yes, NASA sees a need to modernize employment policies and practices in order to maintain a vibrant and productive workforce in the near- and long-term. Already, NASA has had success in reducing hiring times from 90 days to 30 days. Additionally, working with OPM, NASA was recently approved for an extensive Direct Hire Authority for NASA, covering approximately 3,600 positions across 26 different occupations, authorized for the next 5 years. In addition, we are aggressively working to fill critical positions with our limited authority for excepted service positions designated in the Space Act (U.S. Code 51, Chapter 201, Section 20113(b)(1)). In order to attract, assign, and retain our Nation's best and brightest minds, NASA continues to evaluate programs already utilized in other Federal agencies with a large STEM workforce (i.e., National Nuclear Security Administration, DoD Research Labs, Intelligence Agencies, National Institute of Standards and Technology). Such programs include pay-banding, use of labor market sensitive pay setting, pay-for-performance, other financial and placement incentives, classification simplicity, and mobilizing "talent to task" via talent-based placement. NASA acknowledges that Congressional authorization would be needed to implement similar authorities for NASA.

Question 28:

The Administration has expressed interest in public-private partnerships. When used appropriately, funded Space Act Agreements are a useful tool to advance partnerships. NASA's current policy limits the use of funded Space Act Agreements to cases where contracts, grants, and cooperative research and development agreements cannot achieve agency objectives. This ensures that there is proper oversight of the use of funded Space Act Agreements. Does NASA intend to keep this policy in place?

Answer 28:

Yes, NASA intends to keep its policy in place in regard to the use of funded SAAs—that is, that such agreements are only used in cases where contracts, grants, and cooperative research and development agreements cannot achieve Agency objectives. Such instances have been very rare, as NASA has been able to effectively utilize Federal Acquisition Regulation (FAR)-based procurement mechanisms such as contracts to meet Agency objectives when a transfer of funding to a partner is involved. For example, in August 2018, NASA selected six U.S. companies to develop 10 "tipping point" technologies that have the potential to significantly benefit the commercial space economy and future NASA missions,

including lunar lander and deep space rocket engine technologies. Another example would be the Commercial Lunar Payload Services (CLPS) contracts awarded to nine U.S. companies in November 2018, making them eligible to bid on NASA delivery services to the lunar surface as one of the first steps toward long-term scientific study and human exploration of the Moon and eventually Mars.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Waltz

Question 1:

I have heard that NASA recently decided to qualify a new source of ammonium perchlorate for the first Space Launch System Flight Support Booster (FSB-1). Given that ammonium perchlorate is the largest propellant component of each SLS solid rocket booster, is this true, and is the new source foreign or domestic? Does NASA intend to use the new source in future launches? If so, has NASA analyzed what this will do to the existing domestic industrial base for ammonium perchlorate and solid rocket motors more broadly, including the effects on national security systems?

Answer 1:

As part of a multi-year affordability initiative, NASA has been investigating alternative sources of ammonium perchlorate (AP) because the price for the sole domestic source was rising to unacceptable levels. As part of that plan, we did purchase enough AP from a foreign source (at a much reduced price) to qualify that source with the Flight Support Booster (FSB-1) static motor test. NASA has maintained keen awareness of the industrial base issues related to solid rocket motor production and co-authors with the Department of Defense (DoD) a semi-annual report to Congress on the AP industrial base. NASA worked closely with the DoD, and they concurred that NASA's qualification of this second source does not harm U.S. national security interests. Since AP is the largest material component in the Booster propellant, NASA's goal is to have multiple sources available for AP such that market competition will keep the prices down. In fact, NASA is currently buying a significant amount of U.S.-sourced AP concurrent with qualification of the foreign-sourced AP. NASA's goal is to ensure that there is a continued source of AP for our uses, and will continue to monitor the health of the U.S. solid rocket motor industrial base in concert with the DoD and national security needs.

Question 2:

NASA uses what's called Enhanced Use Lease Authority with GSA at Kennedy Space Center (KSC). This authority allows excess property to be utilized by commercial entities and up to 65 percent of the lease proceeds can then be used on common use infrastructure projects at KSC. This leasing authority is set to expire, right when we need more investment at Kennedy to meet bold

objectives, not less. Can you please speak to the importance of the Enhanced Use Lease agreement and its impact on crucial infrastructure at the KSC that benefits all spaceport users?

Answer 2:

NASA's Enhanced Use Leasing (EUL) authority allows all NASA Centers to enter into leases of underutilized non-excess Agency real property with private sector entities, academic institutions, and state and local governments. This authority does not require any involvement from the General Services Administration. Under its EUL authority, NASA may retain lease revenues, thereby positioning the Agency to reduce operating costs, incrementally improve facility conditions, and improve mission effectiveness. The retention of proceeds under EUL authority improves NASA's ability to address facility and maintenance issues in a timely way, thereby reducing the rate of increase of NASA's overall deferred maintenance, currently over $2.3 billion. Since tenants pay consideration at fair market value, NASA has realized net proceeds that have been used to make necessary repairs to infrastructure and to invest in energy savings projects which have helped to reduce utility costs. NASA considers its current EUL authority a valuable tool to aid in the preservation of unique, non-excess assets, rather than allowing them to fall into disrepair.

At the Kennedy Space Center (KSC), EUL authority has enabled leases with diverse partners including communications service providers, media and media support organizations, and solar facilities, as well as the State of Florida and commercial space industry partners. Late in 2018, using NASA's EUL authority, KSC executed new land leases with two major commercial partners SpaceX, and Blue Origin. Under these leases, the partners will use and occupy parcels of unutilized, undeveloped land that is a part of KSC's buffer zone for construction of facilities to support their respective spaceflight hardware and launch vehicle design and manufacturing operations. Also late in 2018, KSC used NASA's EUL authority to enable Florida Power and Light to construct a 470-acre solar power facility. At KSC, EUL revenue proceeds have enabled energy and sustainability upgrades to facilities and mechanical repairs and system upgrades, such as oxygen system upgrades. These facility and infrastructure maintenance, capital revitalization, and improvements enhance the delivery of required services not only to NASA's facilities at KSC, but also to KSC's spaceport partners, particularly those engaged in commercial aerospace activities. KSC continues to seek opportunities for EUL partnerships that are compatible with NASA's mission and support appropriate and responsible management of its real property.

NASA's current EUL authority will expire on December 31, 2019. The loss of EUL authority, would cause an increase in underutilized and/or vacant NASA facilities requiring ongoing maintenance to prevent them from deteriorating. Over time, a continuation of NASA's EUL authority on an annual renewal basis, though certainly preferable to an outright loss of the authority, will create a level of uncertainty regarding its use as a strategic facilities planning tool. NASA's potential partners often are seeking longer-term lease arrangements for the stability of their operations and the prospects for reasonable return on reutilization development investments.

Uncertainty about the possibility of future renewals or extensions may have a chilling effect on the ability of NASA centers to attract the type of compatible business and partnership activities that have contributed to successful revitalization efforts such as those at KSC in recent years. As such, a longer-term EUL authority would provide a more stable, reliable framework for NASA to undertake out-lease decisions going forward.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"A Review of the NASA Fiscal Year 2020 Budget Request"

Questions for the Record to:

Administrator Bridenstine

Submitted by Congresswoman Herrera Beutler

Question 1:

Last year's budget request stated that NASA's Office of Education lacked outcome- related data to demonstrate the effectiveness of its programs. NASA is once again proposing the cancellation of this program. Does NASA have a clearer understanding of the effectiveness of its education-related programs within the mission directorates?

Answer 1:

NASA has spent the last two years analyzing ways to optimize Agency Science, Technology, Engineering and Mathematics (STEM) efforts as a whole. For example, NASA recently completed a deep-dive assessment of the Agency's Education and Outreach efforts, known as a Business Services Assessment (BSA). During this assessment, a core team collected data from across NASA, conducted surveys and interviews with internal and external stakeholders, benchmarked external organizations and performed a detailed assessment of existing Education and outreach efforts. Based on this analysis, NASA created a more seamless approach to eliminate redundant functions and duplication of efforts, and fill in existing gaps in order to better serve the STEM engagement community. It also established the STEM Engagement Council (SEC), which is the Agency's governance body accountable for NASA's comprehensive set of STEM engagement functions and activities. Building on the BSA work, the Office of STEM Engagement (OSE) is currently undergoing a Mission Support Future Architecture Program (MAP) Project to realign the mission support structures to improve efficiency in order to implement an integrated STEM function with a unified approach that will provide a higher return for NASA missions and the Nation's future STEM workforce.

As further proof of NASA's dedication to STEM outreach, NASA Administrator Bridenstine recently established the NASA Advisory Council STEM Engagement Committee in order to provide consensus advice and make recommendations regarding NASA's important role of inspiring the next generation and having it be recognized by the whole of Government. Committee Members represent external STEM stakeholders such as U.S. universities and museums and industry associations. NASA is also actively supporting the National Science and Technology Council's Committee on STEM Education endeavors, with Administrator Bridenstine serving as the Committee's Co-Chair. The Committee's

recent report, *Charting a Course for Success: America's Strategy for STEM Education*, lays out the federal Government's role in furthering STEM education by working with state, local, education, and American employer stakeholders to build a STEM-proficient citizenry, create a STEM-ready workforce and remove barriers to STEM careers, especially for women and underrepresented groups.

Most of NASA's current data regarding its STEM outreach efforts focuses on outputs of its education activities (e.g., number of students and educators reached). NASA will continue to monitor its efforts to share the STEM message with diverse groups, including women and individuals from underrepresented and underserved groups, pledging to use these results as a stepping stone for improved and expanded STEM outreach efforts. To this end, NASA is working on capturing improved demographics, while recognizing that demographics identification at NASA events is voluntary. Additionally, NASA will continue to engage the public and other key stakeholders in its activities, and work to build an open, transparent and participatory organization. Through strategic use of NASA assets in its STEM education offerings, NASA will share its inspirational activities with a broader audience.

It is important to understand that NASA's STEM education and outreach efforts have always occurred beyond the walls of the Education Office (e.g., internships managed by our Mission Directorates, our Speaker's Bureau which sends NASA scientists and engineers to meet with educational and civic organizations, and NASA employees who are authorized to use work hours to mentor local students in STEM activities). And these are just a few of the STEM activities that NASA employees across the Agency proactively engage on every day. Therefore, even if NASA's Office of STEM Engagement is eliminated, 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, while more closely aligning Agency STEM efforts with our Mission Directorates and their missions.

Question 2:

The INSPIRE Women Act showed Congress' continued support for NASA's initiatives to encourage young women and men to join careers in aerospace. How would the closing of the Office of Education influence theseprograms?

Answer 2:

NASA's overall portfolio of STEM/outreach activities will continue to provide opportunities to reach the demographic targeted by the INSPIRE Women Act[1]. Currently, a diverse set of events and activities is developed and sponsored by NASA

[1] It is important to note that NASA public engagement and education activities may not target a single gender, and thus, they are instead developed to reach both genders.

functional offices, Mission Directorates and their programs and projects, and by NASA Centers – all of which have the capacity to effectively inspire, engage and educate girls and young women in STEM. Going forward, NASA educational outreach activities will continue to leverage the Agency's unique mission of research and discovery as a powerful context for inspiration and student learning. Additionally, NASA will continue to work toward attracting and retaining diverse employees in STEM career fields while also providing student access to NASA's world-class research and technology facilities, mission data and Agency technical experts.

Specifically, The INSPIRE Women Act (P.L. 115-7) directed NASA to encourage women and girls to study STEM and to pursue STEM careers. NASA's efforts in this area span across the scope of NASA's endeavors in public engagement and education, with a focus on mentorship and opportunities that provide all students, including young women and girls with experiences interacting with NASA's women in action. NASA endeavors to provide unique opportunities for K-12, undergraduate and graduate students to be exposed to STEM through a spectrum of engagement. Activities that reach the targeted demographic, while fulfilling a broader purpose, include:

- NASA astronaut appearances,
- Speakers Bureau, Girls & Boys mentoring opportunities,
- Aspire to Inspire website, and
- Summer Institute in Science, Technology, Engineering and Research.

The spectrum of NASA's activities provides excellent opportunities to reach young women and girls. NASA will pull from various knowledgeable resources within the Agency to help expand the plan for future engagement.

For more information about how NASA is implementing the goals of P.L. 115-7, please refer to a report NASA provided to the Committee in July 2017, entitled: NASA Response to the INSPIRE Women Act (P.L. 115-7).

Question 3:

This FY 2020 budget request for NASA is $21.019B. The Obama Administration's last budget request (FY 2017) planned to request $19.879B in FY 2020. How does the additional $1.14B requested this year enable exploration, science, and aeronautics?

Answer 3:

The increase of $2.7B (including the budget amendment) primarily supports NASA's mandate to land the first American woman and next American man at the South Pole of the Moon by 2024, followed by a sustained presence on and around the Moon by 2028. The FY 2020 President's Budget submit increases the Human Exploration and Operations Budget in the Advanced Cislunar and Surface Capabilities Program, the Gateway Program, the Space Launch System Program and the Orion Program; all of which are critical to a 2024 human lunar landing. Additionally the request initiates a

Mars Sample Return mission and enables launch of the Europa Clipper mission in 2023. The FY 2020 Aeronautics funding level is relatively consistent with the direct portion of the FY 2017 President's Budget.

Question 4:

In 2013, this Committee heard testimony that 80 percent of NASA's infrastructure was beyond its constructed design life. Is this still the case? What can we do to ensure a key component of our nation's aerospace infrastructure does not fall into disrepair?

Answer 4:

NASA owns and manages a portfolio of facilities and real property with a total footprint of more than 500 square miles with a current replacement value of approximately $38B. Of that value, 80 percent is invested in constructed buildings and structures, predominantly technical in purpose and use. Likewise, as you note, 80 percent of NASA's facilities are more than 40 years, old and some have been in inventory for 80 years. Older facilities are more difficult and costlier to maintain, and are not designed to efficiently support the requirements of today's highly sensitive, technically evolved spacecraft and related hardware and systems. The advanced age of many of NASA's technical facilities also means that, despite ongoing maintenance, there is an intrinsic decline in quality and condition of the facilities, which creates risk to programs and projects that must be managed.

A challenge to managing NASA's highly technical programs is maintaining and modernizing facilities that were designed for an earlier age and purpose. NASA is addressing these challenges with infrastructure renewal policies that are founded on strategic facilities replacement goals for a gradual 25 percent Agency-wide reduction in facilities footprint over 20 years, as obsolete facilities are demolished and replaced with new, flexible-use, energy-efficient, sustainable structures. As these strategies are implemented, NASA continues to contend with the challenge of managing the demands of over $2.3B in deferred maintenance requirements. While NASA has made progress in holding steady the rate of increase through aggressive revitalization plans and demolition across its Centers, the ability to effect measurable reversal in the growth of these deferred requirements has remained elusive.

A well-functioning, efficient and cost-effective infrastructure is necessary for the support of NASA's mission requirements, and has a direct bearing on the level of risk to NASA mission objectives that must be managed. The availability of sufficient resources for NASA to meet these challenges of sustaining its infrastructure remains more critical than ever. NASA's FY 2020 budget request includes critical funding for construction and environmental projects to address these significant challenges. This funding will be important to enable NASA Centers to undertake actions that carry the Agency forward toward its infrastructure management objectives, including replacing obsolete capabilities with facilities that meet the demands of the missions of tomorrow.

Appendix II

Additional Material for the Record

ADDITIONAL RESPONSES SUBMITTED BY MR. JAMES F. BRIDENSTINE

Material requested for the record on page 29, line 591, by Representative Bonamici during the April 2, 2019 hearing at which Administrator Bridenstine testified.

Answer:

The PACE mission builds on the legacies of NASA missions currently on orbit (e.g., the MODIS instrument on Aqua and Terra and the VIIRS instruments on Suomi-NPP and NOAA-20) and several international efforts (e.g., the OLCI instrument on the ESA/EUMETSAT Sentinel-3A and -3B missions). These satellite instruments, as well as PACE, all provide global ocean color, cloud, and aerosol data records at a nominal ~1-kilometer spatial resolution every two to three days. However, the quality and breadth of scientific data on these historical and current missions are not identical to what the PACE mission would provide.

Material requested for the record on page 69, line 1582, by Representative Casten during the April 2, 2019 hearing at which Administrator Bridenstine testified.

Answer:

CLARREO-Pathfinder is a reflected solar spectrometer instrument planned for flight on the International Space Station. It has two objectives:

1. Demonstrate the ability to conduct on-orbit calibration, to internationally-recognized measurement standards, with higher accuracy than is possible on current on-orbit Earth observing sensors; and
2. Demonstrate the ability to use that improved measurement accuracy to serve as an in-orbit reference for inter-calibration of other key satellite sensors across the reflected solar spectrum.

Several instruments set to operate in the timeframe of CLARREO-Pathfinder will obtain data on the Earth's radiation budget that are similar to those that would be collected by CLARREO-Pathfinder. However, they will do so with lower absolute accuracy than CLARREO-Pathfinder is being designed to achieve. The second objective is a unique feature of this mission, and will enable the transfer of CLARREO-Pathfinder's accuracy standards to other missions, in particular those with the Clouds and the Earth's Radiant Energy System (CERES) and Visible Infrared Imaging Radiometer Suite (VIIRS) instruments, on the Suomi-NPP and Joint Polar Satellite System missions. No current or planned instruments have the cross-calibration capabilities of the CLARREO-Pathfinder mission.

While the PACE mission and CLARREO Pathfinder would provide additional capabilities over existing satellites, funding enhancements (estimated to cost a total of almost one billion dollars) in these areas is not a priority in the current fiscal environment. The Budget continues to support a robust Earth-observing program that sustains existing ocean and climate remote-sensing capabilities.

Material requested for the record on page 69, line 1586, by Representative Casten during the April 2, 2019 hearing at which Administrator Bridenstine testified.

Answer:

We do not have knowledge of who made these specific comments. Since neither mission has been launched (the data is not currently available), there would be no impact to existing abilities. However, future NASA research advances in these areas would be limited.

Material requested for the record on page 102, line 2412, by Representative Gonzalez-Colon during the April 2, 2019 hearing at which Administrator Bridenstine testified.

Answer:

NASA received the following appropriated funds associated with hurricanes/tornadoes during FY 2018 & FY 2017.

In FY 2018 $81.3M appropriated

$59.0M allotted to JSC for Hurricane Harvey

$22.3M allotted to KSC for Hurricane Irma

In FY 2017 $183.4M appropriated

$109.0M allotted for Tornado damage at Michoud

$74.4M allotted for Hurricane Matthew (KSC)

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