

**NASA MISSIONS AND PROGRAMS:
UPDATE AND FUTURE PLANS**

HEARING

BEFORE THE

**COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE**

ONE HUNDRED SIXTEENTH CONGRESS

SECOND SESSION

—————
SEPTEMBER 30, 2020
—————

Printed for the use of the Committee on Commerce, Science, and Transportation



Available online: <http://www.govinfo.gov>

—————
U.S. GOVERNMENT PUBLISHING OFFICE

WASHINGTON : 2023

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED SIXTEENTH CONGRESS

SECOND SESSION

ROGER WICKER, Mississippi, *Chairman*

JOHN THUNE, South Dakota	MARIA CANTWELL, Washington, <i>Ranking</i>
ROY BLUNT, Missouri	AMY KLOBUCHAR, Minnesota
TED CRUZ, Texas	RICHARD BLUMENTHAL, Connecticut
DEB FISCHER, Nebraska	BRIAN SCHATZ, Hawaii
JERRY MORAN, Kansas	EDWARD MARKEY, Massachusetts
DAN SULLIVAN, Alaska	TOM UDALL, New Mexico
CORY GARDNER, Colorado	GARY PETERS, Michigan
MARSHA BLACKBURN, Tennessee	TAMMY BALDWIN, Wisconsin
SHELLEY MOORE CAPITO, West Virginia	TAMMY DUCKWORTH, Illinois
MIKE LEE, Utah	JON TESTER, Montana
RON JOHNSON, Wisconsin	KYRSTEN SINEMA, Arizona
TODD YOUNG, Indiana	JACKY ROSEN, Nevada
RICK SCOTT, Florida	

JOHN KEAST, *Staff Director*

CRYSTAL TULLY, *Deputy Staff Director*

STEVEN WALL, *General Counsel*

KIM LIPSKY, *Democratic Staff Director*

CHRIS DAY, *Democratic Deputy Staff Director*

RENAE BLACK, *Senior Counsel*

CONTENTS

	Page
Hearing held on September 30, 2020	1
Statement of Senator Wicker	1
Statement of Senator Cantwell	2
Statement of Senator Gardner	15
Article dated March 1, 2019 from <i>CNBC—The Bottom Line</i> entitled, “1 in 5 corporations say China has stolen their IP within the last year: CNBC CFO survey” by Eric Rosenbaum	16
Article dated May 12, 2020 from <i>SPACENEWS</i> entitled, “Space Force vice commander: China can’t be allowed to buy bankrupt U.S. space companies” by Sandra Erwin	19
Article dated September 4, 2020 from <i>REUTERS</i> entitled, “Exclusive: White House asks U.S. agencies to detail all China-related funding” by David Shepardson	20
Statement of Senator Udall	23
Statement of Senator Capito	25
Statement of Senator Peters	27
Statement of Senator Thune	29
Statement of Senator Sinema	31
Statement of Senator Sullivan	33
Statement of Senator Blumenthal	35
Statement of Senator Rosen	37
Statement of Senator Scott	38

WITNESSES

Hon. Jim Bridenstine, Administrator, National Aeronautics and Space Admin- istration	4
Prepared statement	5

APPENDIX

Response to written questions submitted to Hon. Jim Bridenstine by:	
Hon. Marsha Blackburn	43
Hon. Maria Cantwell	43
Hon. Amy Klobuchar	45
Hon. Tom Udall	47
Hon. Gary Peters	50
Hon. Jon Tester	52
Hon. Jacky Rosen	53

NASA MISSIONS AND PROGRAMS: UPDATE AND FUTURE PLANS

WEDNESDAY, SEPTEMBER 30, 2020

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 10 a.m., in room SR-253, Russell Senate Office Building, Hon. Roger Wicker, Chairman of the Committee, presiding.

Present: Senators Wicker [presiding], Thune, Sullivan, Gardner, Moore, Young, Scott, Cantwell, Blumenthal, Udall, Peters, Sinema, and Rosen.

OPENING STATEMENT OF HON. ROGER WICKER, U.S. SENATOR FROM MISSISSIPPI

The CHAIRMAN. Alright. This hearing will come to order. 2020 has been a year of challenge and triumph for America's National Space Agency. The COVID 19 pandemic has disrupted planning and day to day operations, but NASA and its commercial partners have achieved many successful outcomes. These include launching American astronauts to the International Space Station and returning them safely to Earth, and returning that launch vehicle safely to Earth, launching a perseverance rover to Mars and preparing the Space Launch Systems, SLS, rocket and Orion crew capsule for the first Artemis deep space exploration program mission next year.

I am pleased that NASA Administrator Jim Bridenstine is here to provide us with an update on NASA's missions and programs and the agency's plans for the future. Further progress on the Artemis program is critical to achieving the goals of landing the first woman and the next man on the Moon by 2024 and establishing a sustainable presence on or around the lunar surface by 2028. Congress has given clear support for many key components of Artemis, notably the SLS rocket, the Orion crew capsule, Human Lander System competition and various rovers and instruments to study the lunar surface. Last week, Administrator Bridenstine announced a detailed plan for the Artemis program, projecting total cost of \$28 billion between Fiscal Years 2021 and 2025.

Continuing bipartisan support for Artemis is essential, but members need confidence in NASA's long term plan. I hope the Administrator will lay out the detailed cost and schedule for Artemis to help give us that confidence. The Artemis program receives a justifiable—justifiably large amount of attention, but we should also recognize the tremendous success of the commercial crew program.

On May 30, the NASA, SpaceX team launched American astronauts on American rockets from American soil for the first time since 2011. Commercial crew represents a true public, private partnership where the Government buys services from space companies. It would be helpful if the Administrator would highlight how NASA is implementing lessons learned from Commercial Crew development.

In November of last year, this committee passed the NASA Authorization Act, demonstrating strong support for Artemis and Commercial Crew. The legislation also strongly supported NASA's key science priorities, aeronautics research, planetary exploration, STEM education, and other initiatives. Today, Administrator Bridenstine can provide an update on these missions and describe any major impacts on cost, schedule or operations caused by the pandemic. NASA plays an important role in America's whole of Government approach to securing the space domain for exploration, science, and commerce. Great power competition in space is a reality.

China's space ambitions are well-known and the Chinese Communist Party has devoted enormous resources to military and civil space programs. NASA recently signed a Memorandum of Understanding with the newly created U.S. Space Force to bolster collaboration on standards and best practices for space operations, scientific research, and planetary defense. Administrator Bridenstine may want to comment on the memorandum of understanding and where he sees opportunities for collaboration with the Space Force. Even with this year's successes, program vulnerabilities remain.

As the Artemis program progresses, we should remain vigilant to protect and strengthen international partnerships, particularly those built around the International Space Station and low Earth orbit research. We should ensure that groundbreaking initiatives such as robotic Mars missions and planetary observatories continue making progress.

Maintaining forces—maintaining focus on Artemis and other missions will require continued support and funding from Congress. So I look forward to today's conversation with the Administrator, and now turn to my dear friend and colleague, the Ranking Member, for her remarks.

**STATEMENT OF HON. MARIA CANTWELL,
U.S. SENATOR FROM WASHINGTON**

Senator CANTWELL. Thank you, Mr. Chairman, and thank you for the bipartisan leadership on the NASA reauthorization bill. I was pleased to join you and Senators Cruz and Sinema to author the NASA Authorization Act of 2019. Among other things, this legislation would provide authorization for NASA's human exploration programs, including the lunar lander needed to return humans to the moon. There is agreement between the bill's sponsors about how to proceed on the authorization, and I hope the Senate will consider this important bill this year.

NASA's recent economic impact analysis shows that in 2019, the agency generated more than \$64 billion in economic output, supported more than 312,000 jobs nationwide, and NASA and the space industry, particularly important in the State of Washington,

or space-enabled activities account for \$1.8 billion of our state's economy with notable companies like Blue Origin, SpaceX, and Aerojet Rocketdyne leading the way. Thousands of Washington jobs are dependent on this growing space industry. I always say there is a reason we have the Space Needle.

So 2020 was a significant year for NASA. For the first time in 9 years, NASA astronauts launched to space from the U.S. soil. And for the first time ever, those astronauts launched on a commercial spacecraft, marking the dawn of a new era for NASA. 2021 promises to be an even bigger year for the agency. Two commercial providers will begin regularly carrying astronauts to the International Space Station. 2021 will also see the first launch of NASA Space Launch System, which will return astronauts to deep space in a few years. I am looking forward to watching Americans exit the lunar lander, which will be built in the State of Washington, and step onto the surface of the moon for the first time in more than 40 years. And I am very enthusiastic about the Artemis program, which will put the first woman on the moon.

Now we need more than just that women's first step. We need women and minorities to be represented at every level of NASA and space programs, and so I look forward to working with you and the Chairman on how we increase the diversity in the aerospace industry. Given the many new rockets and spacecraft NASA astronauts will fly over the next decade, it is imperative the agency remain committed to safety.

Safety must always be the top priority, and in order for that to happen, NASA engineers and program managers must have insight into the design and testing of new spacecraft.

A major safety issue for NASA is the threat of orbital debris. Just last week, the space station was forced to maneuver away from a piece of space debris. In February, the Committee held a hearing on threats to space, and I called for increased investment in the mapping of space debris and improved space situational awareness capabilities. So, Mr. Chairman, I know you are also committed to addressing this threat, and I look forward to working with you on that issue. While NASA's human spaceflight programs are often in the spotlight, the agency's other missions and research are also critical to the country.

In Washington, along with many Western states, we face an unbelievable threat from devastating wildfires. NASA satellites provide data that enables disaster management teams to measure the intensity and development and fires as they burn. And I also want to highlight NASA's Space Grant program. Again, a consortium at the University of Washington is doing tremendous work to engage high school students and undergraduates in these areas of research and study, which I think just helps us get the next generation of workforce.

The COVID 19 pandemic has impacted many NASA programs as well as the people who support them, whether they are employees or contractors or researchers, so I look forward to hearing how this committee might work with NASA to keep the program on track while keeping people safely employed. This is a challenge, but obviously we want to keep moving ahead, so we will look forward to your comments and testimony, Administrator Bridenstine.

So thank you for being here today, and again, Mr. Chairman, thank you for holding this important hearing.

The CHAIRMAN. I think I heard the State of Washington mentioned several times in Senator Cantwell's opening Statement. Clearly, I should have mentioned in my opening Statement the important role of the State of Mississippi in all of the activities that we have planned, particularly the Stennis Space Center in Hancock County, Mississippi.

So at this point, Administrator Bridenstine, we have your prepared Statement consisting of seven pages and small type. We will enter that into the record at this point. And you are recognized for 5 minutes or so to summarize your Statement.

**STATEMENT OF HON. JIM BRIDENSTINE, ADMINISTRATOR,
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

Mr. BRIDENSTINE. Thank you, Chairman Wicker and Ranking Member Cantwell. It is an honor to be here. I will tell you, I want to start by thanking you for the support we received in the CARES Act, which ultimately enabled us to move forward on some of our very important missions. We call them mission essential functions of NASA. So we needed that, you know, personal protective equipment, we needed the ability to make sure that our crews could socially distance and do all of the things necessary to be safe, and the CARES Act was really a part of that, and we thank you for that.

So NASA is really up to some really amazing things. The two of you highlighted them very well. Low Earth orbit, we are commercializing very rapidly. We have been underway with commercial resupply now for a number of years, and now we are moving forward with Commercial Crew, which we are all very, very excited about. Demo two is complete. That was a test flight. Here at the end of October we are going to launch Crew 1. We are going to have a full complement of four astronauts, including one international partner from Japan. And so this is a very exciting time for the agency as we move rapidly to commercialize space. But it is not just about commercial resupply and Commercial Crew, we also want commercial space stations themselves eventually.

The International Space Station has been an amazing asset for the United States. It still is and it will be for years to come. But we all know that a day is going to come when it comes to the end of its useful life. And when that happens, we need to have funded the resources necessary to commercialize low Earth orbit for habitation. We want to make sure that in the United States, and with your help, we can ensure that we have no gap in low Earth orbit. We think about Apollo, we had—during the Apollo era, as much as we loved it, it came to an end, and we had a gap of about 8 years before Space Shuttle. And then after Space Shuttle retired, we had another gap of about 8 years before Commercial Crew.

And we want to make sure that there is no gap in low Earth orbit for the United States of America as we transition from the International Space Station to commercial space stations. But as both of you have identified, what is happening in low Earth orbit, as awesome as it is, pales in comparison to what we are going to see when we land the first woman and the next man on the surface

of the moon under the Artemis program. We are going to the moon for a lot of really important reasons, but the chief reason to go to the moon is because it accelerates our path to Mars. And we believe it is important for the first person to land on Mars to be an American astronaut. And we want to make sure that when we do go to Mars, we go with our international partners.

This is about American leadership. And, of course, what we just saw, just in fact yesterday, Japan announced its biggest budget for its space agency in its history. In fact, it was a 50 percent increase over the previous year. That is a massive increase for a nation like Japan. And they are focusing it on the Artemis program. They are focused on supporting us as we lead the world to the moon. I will say that that is not unique though. We have seen budgets coming from Europe that are also increasing, commensurate with the Artemis program and NASA's budget.

So a lot of really exciting things in the future, and, of course, I am grateful to you, Chairman Wicker, and Ranking Member Cantwell, for the continued bipartisan support for these important missions for our country. So with that, sir, I will yield back whatever time I have remaining and certainly open to any questions.

[The prepared statement of Mr. Bridenstine follows:]

PREPARED STATEMENT OF JAMES BRIDENSTINE, ADMINISTRATOR,
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Overview

Chairman Wicker and Members of the Committee, I am pleased to have this opportunity to discuss NASA's Fiscal Year 2021 budget request. We are proposing a budget of \$25 billion, an increase of 12 percent over our request for FY 2020. This budget both reinforces our innovative human space exploration program and maintains strong support for NASA science, aeronautics, and technology research. This investment, coupled with the unmatched talent of NASA's workforce, will enable America's continued leadership in space, propelling the United States toward a new era of technical achievement and scientific discovery.

Regarding the COVID-19 pandemic, I would like to assure you that keeping the NASA workforce safe has been our highest priority during this challenging period. Since mid-March, more than 90 percent of our workforce has been in a telework status, and our employees have continued to perform NASA's important missions with distinction. Only a limited number of employees performing mission-essential work for the protection and safe operation of critical Agency infrastructure and a few select missions (*e.g.*, Commercial Crew Program Demo-2 launch and Mars Perseverance launch preparations) were authorized to be on site. The amazing productivity of our workforce during the pandemic has proven that more work could be done remotely in the future. We will use lessons learned in our "Future of Work" planning.

NASA's FY 2021 request funds Artemis, the Agency's plan to land the first woman and the next man on the surface of the Moon in 2024 as part of a Moon to Mars campaign of exploration. Most urgently, the FY 2021 request includes more than \$3 billion for the development of a Human Landing System (HLS). The budget fully supports the Space Launch System (SLS) rocket, Orion spacecraft, the Gateway, the ground systems, infrastructure, space technologies, and science needed for Artemis. The Moon to Mars campaign includes efforts from across the Agency funded at \$12.37 billion in FY 2021. This budget provides the resources we need in FY 2021 to send humans to the Moon in 2024. There, we will prove the technologies and systems for long-term exploration and utilization required to accomplish the great, national goal of sending humans to Mars. The Artemis missions are a key step to supporting human missions to Mars, and funding for Artemis at the levels requested is the best way to advance the timeline for these missions.

Human Exploration and Operations

The request provides the FY 2021 resources NASA's Human Exploration Operations Mission Directorate needs to support a robust exploration program. The FY 2021 request includes \$8.76 billion for Deep Space Exploration Systems, and \$4.19

billion for Low-Earth Orbit and Spaceflight Operations, including the ISS and Space Transportation—both commercial crew systems development and ongoing crew and cargo transportation services that resupply the ISS.

NASA is building a deep space launch and crew system—the Orion spacecraft, the heavy-lift SLS launch vehicle, and the related Exploration Ground Systems (EGS)—to support the Artemis effort. NASA’s plan to send the first woman and the next man to the surface of the Moon begins with two test flights: Artemis I and Artemis II. Artemis I will use the SLS rocket to send an uncrewed Orion spacecraft around the Moon to test the system and reduce risk. Artemis II will be the first crewed mission and will serve to demonstrate the crewed system. Following these test flights, Artemis III will launch a crew of four using SLS and Orion on a mission to the surface of the Moon. Earlier this year, NASA completed a detailed cost and schedule assessment for the launch of Artemis I, which included a joint cost and schedule confidence level analysis of the SLS and EGS programs. Based on these results, NASA intends to target a November 2021 launch date for Artemis I. NASA is actively managing impacts to Artemis II based on the Artemis I schedule changes, and is currently planning to an August 2023 launch readiness date.

The Gateway in lunar orbit will be capable of supporting visiting vehicle docking, deployments, and operations. It will initially consist of the Power and Propulsion Element and the Habitation and Logistics Outpost. Once Gateway is launched and becomes operational in lunar orbit, the Gateway Logistics Element will deliver supplies for outfitting and surface expeditions. International partnerships in the Gateway will allow NASA to leverage habitation, robotics, and communications capabilities. The Gateway is a key aspect of the sustainability of the Artemis effort and future missions to Mars.

On April 30, 2020, NASA announced the selection of three U.S. companies to design and develop human landing systems for the Artemis program: Blue Origin of Kent, Washington; Dynetics (a Leidos company) of Huntsville, Alabama; and SpaceX of Hawthorne, California. NASA’s partners will refine their concepts through the contract base period ending in February 2021. NASA will later select firms for development and maturation of sustainable lander systems followed by demonstration missions. NASA intends to procure commercial transportation services to the lunar surface.

At the lunar South Pole, NASA and our partners will develop an Artemis Base Camp to support longer lunar expeditions on the surface. The three proposed primary mission elements of Artemis Base Camp are: the Lunar Terrain Vehicle (unpressurized rover) to transport suited astronauts around the site; the habitable mobility platform (pressurized rover) that can enable long-duration trips away from Artemis Base Camp; and the foundation surface habitat that will accommodate four crew on the lunar surface and anchoring Artemis Base Camp and the U.S. presence at the South Pole. The Artemis Base Camp will demonstrate America’s continued leadership in space and prepare us to undertake humanity’s first mission to Mars.

As part of the Artemis effort, NASA will leverage interagency partnerships, expanding relationships with other U.S. Government agencies to take advantage of their expertise, create mutually beneficial synergies, and ensure ongoing coordination in the pursuit and achievement of the Nation’s space goals. NASA will maintain and grow mutually beneficial international partnerships to lead a global community dedicated to expanding peaceful exploration and use of the Moon and then Mars.

The budget request continues support for the ISS, humanity’s premier home in space over the last 20 years, and commercial cargo resupply services. NASA and our international and commercial partners are conducting critical research on ISS to support our future exploration plans while also supporting basic and applied research that exploits the unique microgravity environment in orbit. ISS supports cutting-edge research on the effects of spaceflight on the human body, as well as research in fluid physics, combustion, and other research areas.

NASA’s Commercial LEO Development program will continue to leverage its resources and capabilities to further expand the commercial market in LEO. The program’s first solicitation award, announced in January 2020, will support the development of a new commercial LEO platform that will initially be attached to the ISS Node 2 forward port. NASA also is seeking proposals from industry for partnerships that will demonstrate free-flying commercial destinations. Furthermore, NASA has opened the ISS for commercial activities, is encouraging private astronaut missions to the ISS, and is seeking other opportunities to partner with industry to stimulate demand for products and services in LEO. It is critically important for NASA to receive the full budget request for this program to ensure that there is no gap in U.S. presence in LEO and also to ensure NASA can continue meeting its microgravity research requirements after ISS retirement.

Through NASA's Commercial Crew Program, American astronauts have resumed launching to ISS from American soil for the first time since the Space Shuttle was retired in 2011. The May 30 launch of SpaceX's Dragon Endeavour Demo-2 marked the beginning of the second spaceflight test of the Crew Dragon craft and its first test with astronauts aboard. Astronauts Robert Behnken and Douglas Hurley conducted a successful mission to the ISS and returned safely to Earth on August 2. This was SpaceX's final test flight and is providing data on the performance of the Falcon 9 rocket, Crew Dragon spacecraft and ground systems, as well as in-orbit, docking, splashdown, and recovery operations. NASA's SpaceX Crew-1 mission is slated for launch from the U.S. to ISS later this year. The crew for this historic mission will be comprised of three NASA astronauts, as well as an international partner astronaut from Japan.

Boeing is currently targeting no earlier than December 2020 for launch of the uncrewed Orbital Flight Test-2 (OFT-2) of its CST-100 Starliner spacecraft, pending hardware readiness, flight software qualification, and launch vehicle and space station manifest priorities. Over the summer, Boeing's Starliner team focused on readying the next spacecraft for its upcoming flight tests as well as making improvements identified during various review processes throughout the beginning of the year. After a successful OFT-2, Boeing and NASA will fly Starliner's first crewed mission, the Crew Flight Test, currently targeted for no earlier than June 2021, with the first post-certification mission, called Starliner-1, tentatively scheduled for no earlier than late December 2021.

Exploration Technology

NASA's FY 2021 request includes \$1.58 billion for Exploration Technology. NASA is enabling technology research and development needs for human space exploration and Artemis, with a near-term prioritization of sustainable lunar surface exploration and exploration of Mars in the long-term. The Space Technology Mission Directorate (STMD) rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies through transparent, collaborative partnerships. These transformative technologies enable NASA's lunar and deep space exploration missions to meet human space exploration needs, as well as foster commercial expansion in LEO, cislunar space, and beyond.

In direct alignment to Artemis and NASA mission needs, investment decisions are driven by the following Technology Thrusts: 1) rapid, safe, and efficient space transportation, emphasizing reusable in-space transportation between Earth, the Moon, Mars and beyond; 2) expanded access to diverse surface destinations, routinely landing crew and cargo on the Moon and eventually Mars; safely and efficiently returning large payloads to Earth; and delivering robotic payloads to challenging new destinations; 3) sustainable living and working farther from Earth, routinely conducting crewed operations beyond LEO working toward a sustainable human presence on the Moon and eventually Mars; technologies to survive and operate through the lunar night; production of propellant and consumables from local resources; and 4) transformative missions and discoveries to reach challenging sites and resources on the Moon, Mars and beyond, and enable rapid, low-cost missions to the Moon, Mars and beyond.

STMD is funding an array of efforts to accelerate NASA's broader Moon-to-Mars campaign: autonomous landing and hazard avoidance; advanced cryogenic fluid management capabilities; rapid and efficient transit propulsion; high-performance spaceflight computing; and advanced materials, and in-space manufacturing and assembly technologies. In the first year of the Lunar Surface Innovation Initiative, NASA kicked off the Polar Resources Ice Mining Experiment project by down-selecting a drill targeted for early lunar surface demonstration. STMD is also investing in an advanced Navigation Doppler LiDAR technology for precision landing on the Moon and other planets that will directly benefit future human and robotic landers. This technology will be demonstrated on the first two of NASA's robotic Commercial Lunar Payload Services (CLPS) missions. In addition, STMD will make strategic surface technology investments critical for future Moon and eventually Mars human missions.

The integrated Space Nuclear Technologies portfolio sets a new path forward to enable long-duration surface missions on the Moon and eventually Mars. This program places a high priority on lunar surface power, but also will continue to make progress on propulsion capabilities to meet the power and propulsion needs for the future exploration of Mars.

Upcoming early-stage innovation activities will investigate areas such as breakthrough propulsion, challenges in deep space human habitation, space-optimized energy systems, radiation protection, and materials. These areas are part of a com-

prehensive approach to efficiently support innovative discovery, progress toward important goals, and the development of exciting new capabilities.

Science

NASA's Science Mission Directorate funds ongoing discovery and exploration of our planet, other planets and planetary bodies, our star system in its entirety, our galaxy, and the universe beyond with domestic and international partners. The FY 2021 budget supports Decadal Survey priorities identified by the science community, including history's first Mars sample return mission, the Europa Clipper, and more advanced Earth observation missions. The request supports more than 110 space missions and approximately 10,000 U.S. scientists, and includes partnerships with 12 other Federal agencies and 60 other nations. The FY 2021 budget request provides \$6.31 billion for Science, including: \$2.66 billion for Planetary Science; \$831 million for Astrophysics; \$414.7 million for the James Webb Space Telescope (JWST); \$633.1 million for Heliophysics; and \$1.77 billion for Earth Science. The budget request will enable NASA to continue advancing a world-class, balanced science portfolio while accelerating our exploration goals for the Moon and Mars.

NASA's Lunar Discovery and Exploration Program is working with several American companies to deliver science and technology to the lunar surface through the CLPS initiative. Under the Artemis program, early commercial delivery missions will perform science experiments, test technologies and demonstrate capabilities to help NASA explore the Moon and prepare for human missions. The first two CLPS launches are targeted for July 2021. This past June, NASA announced that it had selected Astrobotic of Pittsburgh to deliver NASA's Volatiles Investigating Polar Exploration Rover (VIPER) to the Moon's South Pole in late 2023. By searching for water ice and other potential resources, VIPER will help pave the way for astronaut missions to the lunar surface beginning in 2024 and will bring NASA a step closer to developing a sustainable, long-term presence on the Moon as part of the Agency's Artemis program.

In *Planetary Science*, the Mars 2020 Perseverance rover mission launched on July 30, and is on its way to the Red Planet to continue NASA's leadership in the international community and search for signs of ancient life and collect samples to send back to Earth. When it lands in February 2021, it will collect rock and soil samples at the landing site, Jezero Crater. As part of the mission, NASA will deploy the Ingenuity helicopter from the rover in the first demonstration of rotorcraft on another planet. Perseverance will cache samples to be collected by NASA's Mars Sample Return mission in partnership with the European Space Agency (ESA).

Planetary Science also supports: the next Discovery missions, Lucy and Psyche; the Europa Clipper mission, which will conduct over 40 fly-bys of this icy moon; and Dragonfly, a mission to Saturn's moon Titan, currently planned for launch in 2026. A new Near-Earth Object (NEO) Surveillance Mission—a follow-on to NEOWISE—will help NASA complete the Congressional goal to find NEOs at least 140 meters in diameter approximately ten years after the mission begins on-orbit operations. The Double Asteroid Redirection Test, which will launch in July 2021 and deliberately crash into an asteroid moon in fall 2022, will conduct a planetary-defense-driven test of the kinetic impactor technique for preventing an impact of Earth by a hazardous NEO in the future; and NASA's first asteroid sampling mission, the Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx), will touch the asteroid Bennu's surface during its first sample collection attempt, with return to Earth expected in 2023.

Astrophysics takes on the challenge of understanding the vast universe, using new technologies to look back in time to its origins and learn about the evolution of galaxies and stars. The FY 2021 request will enable NASA to follow the decadal-survey-recommended cadence of Astrophysics Explorers; add a new small mission component (Pioneers) to this storied program; support competed missions and research; and continue the development of JWST, which is slated for launch in October 2021. The Hubble Space Telescope, launched and deployed 30 years ago this past April, is still producing incredible science. The Transiting Exoplanet Survey Satellite continues planet hunting as part of its extended mission, providing a growing list of worlds around nearby stars.

The next Decadal Survey on Astronomy and Astrophysics, Astro 2020, is currently underway and is scheduled for release by the National Academies of Science, Engineering and Medicine in 2021. NASA looks forward to the final recommendations and working to implement them.

In order to maintain a balanced science program that optimizes overall scientific return, the FY 2021 budget request again proposes termination of the Nancy Grace Roman Space Telescope, given its significant cost and the need to prioritize spending. This request also includes \$12 million to begin closeout of the Stratospheric Ob-

servatory for Infrared Astronomy (SOFIA), which has annual operating costs of about \$80 million. SOFIA's annual budget is the second most expensive operating Astrophysics mission, and it is less scientifically productive than other missions with similar operating costs.

Heliophysics studies the fundamental properties of our star, the Sun, and how its behavior impacts Earth, our solar system, and the nature of space. This research helps scientists identify the causes and impacts of space weather phenomena, which threaten spacecraft and astronauts, including future explorers of the Moon and Mars, and which can affect technology on and around the Earth. The FY 2021 budget request supports the Heliophysics Space Weather Science and Applications Program and continued coordination with other agencies to enhance space weather prediction capabilities. Also supporting science in Artemis, Heliophysics is developing a space weather instrument suite for the Gateway.

Missions in the Heliophysics System Observatory continue to provide vital information about our Sun, including: Parker Solar Probe, which has now completed four trips close to the Sun; the Ionospheric Connection Explorer, and Global-scale Observations of the Limb and Disk instruments, which are providing comprehensive observations of Earth's ionosphere; and Solar Orbiter, a mission led by ESA, that is orbiting the Sun, looking at different regions from our other instruments.

Earth Science develops and operates a wide array of space-based and airborne missions seeking to improve our understanding of Earth. The FY 2021 budget request supports a variety of missions, including the Orbiting Carbon Observatory-3 on ISS; the ECOSystem Spaceborne Thermal Radiometer Experiment on Space Station instrument; and the Global Ecosystem Dynamics Investigation instrument. NASA also continues progress on Landsat 9, a part of the Sustained Land Imaging Program, planning for a launch in 2021.

In November 2020, NASA plans to launch Sentinel 6A Michael Freilich, a 10-year Earth observation mission, which partners with NOAA, ESA, the European Commission, and the European Organization for the Exploitation of Meteorological Satellites. Sentinel 6A Michael Freilich will measure Earth's changing oceans, providing valuable and long-running data on sea level, ocean circulation and key drivers of our weather, like El Niño and La Niña. In a remarkable gesture earlier this year, the partners renamed the mission after Michael Freilich, NASA's former director of Earth Science.

Consistent with the FY 2019 and FY 2020 budget requests, the FY 2021 request does not support the Plankton Aerosol Cloud Ocean Ecosystem (PACE) and Climate Absolute Radiance and Refractivity Observatory Pathfinder (CLARREO-PF) missions. The PACE mission builds on the legacies of NASA missions currently on orbit and several international efforts. Several instruments set to operate in the timeframe of CLARREO-PF will obtain data on the Earth's radiation budget that are similar to those that would be collected by CLARREO-PF, which was designed as a one-year technology demonstration.

Aeronautics

NASA's FY 2021 budget requests \$819 million for aeronautics research, managed by the Aeronautics Research Mission Directorate, to support continued U.S. global leadership in aviation technology. The Agency conducts aeronautics research to bring transformational advances in the safety, capacity, and efficiency of the air transportation system and to enable breakthroughs in the speed and efficiency of transport aircraft that are the backbone of today's aviation system as well as innovative new aircraft concepts and technologies that will enable new aviation markets. The FY 2021 request will enable NASA to continue developing and maturing new technologies such as advanced configurations like truss-braced high-aspect-ratio wings, small core turbine engines, high-rate composite manufacturing, and electrified aircraft propulsion that the U.S. aviation industry will use in next generation of subsonic aircraft. NASA is also continuing our investment in critical fundamental technologies for hypersonic flight, including systems analysis, hypersonic propulsion, reusable vehicle technologies, and high-temperature materials.

The budget for aeronautics supports the development of X-planes, including NASA's X-59 Low Boom Flight Demonstrator mission, which will fly a quiet supersonic airplane to demonstrate the community acceptability of low-boom technology. In FY 2021, NASA will prepare the X-59 for first flight, and prepare for community overflight tests and deployment. By 2021, NASA will be flying the X-57 Maxwell aircraft to better inform standards development for smaller, all-electric aircraft.

In FY 2021, NASA expects to complete transition of NextGen airspace management tools and data to the Federal Aviation Administration (FAA) for operational integration. NASA will work with FAA to develop a long-term vision for a trans-

formed National Airspace System based on service-based architectures to enable achieving safe, scalable, routine, high-tempo airspace access for all users.

Future generations will utilize flight in new ways to carry out their day-to-day activities through our exciting vision for Advanced Air Mobility (AAM), building on NASA-developed Unmanned Aircraft System (UAS) Traffic Management and UAS capabilities. In FY 2021, NASA will lay the groundwork for AAM through research into concepts and technologies for safe AAM operations, and developmental testing for National Campaign events where industry will demonstrate AAM vehicle and airspace management technologies.

Office of STEM Engagement

The functional office at NASA Headquarters will continue to oversee Agency-wide strategic direction and coordination of NASA's STEM engagement efforts. Through Mission Directorate activities, NASA would continue to create unique opportunities for a diverse set of students.

Mission Support

NASA must have the enabling technical and professional expertise and facilities necessary to efficiently and effectively support its programs. The FY 2021 request funds capabilities and infrastructure needed 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. To address the significant risk to mission success posed by aging facilities and an increasing maintenance backlog, the 2021 budget includes funding critical to infrastructure renewal and divestment of unneeded, costly facilities. In FY 2021, NASA will strengthen cybersecurity capabilities, safeguarding critical systems and data, while also providing funding to modernize NASA's IT systems.

Conclusion

The FY 2021 budget proposed is one of the strongest in NASA history. The reinforced support from the President comes at a critical time as we lay the foundations for landing on the lunar South Pole with the first woman and the next man on Moon by 2024. This budget keeps us firmly on that path.

The CHAIRMAN. Well, thank you very, very much. You recently announced that the Artemis 1 mission will take place at the end of November of next year. Part of the role of my home State of Mississippi is in these testing the Space Launch System, rocket engine. How is the green run testing at Stennis, and is it progressing? And do you have a target date for the full duration hot fire test?

Mr. BRIDENSTINE. Yes, sir. So the green run testing is progressing very well. The rocket—this is the core stage of the SLS rocket. It is proving itself to be an extremely capable system. We still have a good bit of testing in front of us, including the full green run where we fire all four RS-25 engines at the same time. So that is going to be an amazing sight to see. Likely to happen in November. And so we are moving rapidly toward that. We have had some challenges, of course, with some hurricanes.

We have had some other challenges with COVID. But we have also had some successes. And so we are moving forward and we think that the green run test will be done in November, early November. And we also believe that this sets us up for the first launch of the SLS system with an Orion crew capsule in November 2021. And so we are moving rapidly toward that.

The CHAIRMAN. You think we are still on track to meet that November 2021 date?

Mr. BRIDENSTINE. As of right now, yes, sir, we are. There are challenges for sure, and depending on how COVID affects us in the months ahead, it could be more challenging. But I will say, because this is a mission that is so unique, we do have margin in the schedule, we have a reserve in the schedule and in the cost. And NASA

does that for all of its missions. And as of this point, we have not determined that we need to move off of the November date of next year.

The CHAIRMAN. Well, I have been very impressed with how NASA has moved forward on any number of target dates. Let me ask you about the Continuing Resolution, assessing the Continuing Resolution this this week. And obviously that is never ideal, but the COVID 19 pandemic pretty much dictated that. This is a brief C.R.—doesn't carry on into next year. You have spoken about the problem of a long-term Continuing Resolution. If you will, please discuss the broader impacts if we can't get our job done in November and December, what that would mean for your programs?

Mr. BRIDENSTINE. Yes, sir. So the hardest part right now is that human landing system. That human landing system is what right now we are not funded to develop in its entirety. We are funded through what we call the base period. We have got the resources to go through basically February 2021. And so between now and February 2021, I think we are OK. But if we get to February 2021 without an appropriation, that is going to really put the brakes on our ability to achieve a moon landing by as early as 2024. And so it is important to get these appropriations.

I will also tell you, sir, the sooner we get the appropriations, the higher the probability of success. So we are very grateful that I know that the House and the Senate are moving toward a C.R. rather than a shut down. That is—we are very grateful for that. And I speak for the entire NASA workforce when I say that. But I will also say that the sooner we can get an appropriation, the higher the probability of success to the moon landing as soon as 2024.

The CHAIRMAN. That is the appropriation. What about the authorization bill? How important is it to pass an updated authorization bill?

Mr. BRIDENSTINE. So in my view, very important. I was an authorizer in the House of Representatives. And I can tell you what the authorization bill enables me to do as the Administrator is demonstrate that this has strong bipartisan support that is lasting. Appropriations are 1 year in nature and they give us what we need to fund the programs. But an authorization bill—this is a fundamental question I get everywhere I go as the NASA Administrator.

People ask me, how do you ensure that this program doesn't get canceled? Like NASA has had a history of seeing programs get developed and then canceled. And the answer is we need the authorization bill that codifies that what we are doing has broad national consensus and bipartisan support. I think we are there, but putting that into law really would be meaningful for the agency.

The CHAIRMAN. Thank you very much. Senator Cantwell.

Senator CANTWELL. Thank you, Mr. Chairman. Administrator Bridenstine, one of the things that we hear a lot about as, again, we change and innovate is the skill level of the workforce in STEM. We work very hard on STEM education in the State of Washington and certainly want to work on it from a national perspective. So I want to hear your thoughts on what else we need to be doing. What does that skills gap look like? And also interested in NASA's

X-plane flight demonstration program for a transonic truss-braced wing.

One of the things we are very interested obviously in is composites and continuing the development of composite manufacturing. So want to understand what you think we should be doing on that kind of technology for the future as well.

Mr. BRIDENSTINE. Yes. Very, very good questions. And I will tell you, the transonic truss-braced wing has me very excited about the future of aviation. When we think about the value of NASA to the United States of America, a lot of people, they think about space and the moon and Mars and robotic exploration of the solar system. But the aeronautics piece is probably the most impact to the American economy because this is a major export for the country, and we have been leading here for so many generations.

Of course, we have the challenge with the MAX 8. We have had the challenge now with COVID. And when we think about aeronautics, it is kind of—right now, it is being stressed significantly. But I think we have to, as a nation, take this opportunity and lead. And when I say lead, that transonic truss-braced wing is a key to that leadership. We are talking about increasing what we call the aspect ratio of a wing, making it longer and thinner. The big thing that that does is it reduces what we call induced drag, which is the drag you get from the lift created by the aircraft.

Basically, it spreads out the amount of downward thrust that you get from the wing. It does increase what we call parasitic drag from the wing, but that parasitic drag is less than the induced drag. And so overall, you get a much more efficient aircraft. It drives down the amount of fuel that you have to use. It drives down the amount of carbon emissions. It drives down the cost to the airlines.

The challenge with that high aspect ratio wing, the challenge with that is that it becomes really long and thin and so it doesn't have the structure necessary to hold up, you know, a large body aircraft. So I am a huge proponent of that. We have been advocating, you know, for that inside, not just the agency, but inside the Administration in general and we are getting some traction on it. And any support that you can provide would be fantastic. Well, let's see, the—

Senator CANTWELL. STEM—well, STEM and—so in this case, this is a composite issue, right. And so we need more composite R&D and more understanding of them on the composite manufacturing side.

Mr. BRIDENSTINE. Yes. So this is, again, very important. When it comes to STEM, we need that next generation workforce and so we have got to be inspiring people at a young age. I think the best thing NASA can do for encouraging people to go into STEM is inspire them and do these stunning missions like landing the first woman on the moon and those kind of activities. We are also very involved at the mission directorate level in funding programs like First Robotics, which is a capability that gets high school kids and even younger involved in robotics.

So we do those things. Direct impact to NASA missions. If you look at, you know, robotics on Mars and robotics throughout the solar system with satellites and orbiters of other planets. So I

think there is a lot that NASA does and we need to continue to do for STEM.

Senator CANTWELL. Yes, I don't know what it is about material science, but we have been able to attract more women. Structural engineering may not have been something that immediately appealed to them, but certainly we attracted them in aviation. We are having more success on the material science side.

And I don't know if that is a marriage of chemical engineering and other things, but I think we should figure out how to put this challenge to, as you said, the youngest of Americans. And I don't know why this isn't something we hear about more often given that you are talking about, again, fuel efficiency, American jobs, leadership, you know, all of these things that would come from this. This is, you know—it is as exciting as the other missions too. So, thank you.

Mr. BRIDENSTINE. Yes, ma'am.

The CHAIRMAN. Administrator Bridenstine, the Ranking Member mentioned space debris. So let me—let's drill down on that just a little bit. Is the frequency of avoidance maneuvers increasing? Just a few days ago, NASA maneuvered the International Space Station to avoid a piece of unknown space debris. This happened now three times this year. So is that increasing?

Mr. BRIDENSTINE. Yes, sir, it is. Now, I will tell you—so this year, we have maneuvered the space station three times in order to avoid orbital debris. That has not happened since 2015. And now in this year, we have done it three times.

The CHAIRMAN. So is that just a coincidence?

Mr. BRIDENSTINE. I don't—I don't think that this is a coincidence. I will also say in the last 2 weeks, or maybe 3 weeks at this point, we have had three potential conjunctions that made us very nervous apart—and that is in the last two or 3 weeks, apart from the maneuver that we actually had to make. So—

The CHAIRMAN. Close calls.

Mr. BRIDENSTINE. Yes, sir.

The CHAIRMAN. We knew about them, but it was far enough away that you didn't have to maneuver.

Mr. BRIDENSTINE. Yes, sir. So we monitored them very closely and we made a determination that it didn't require a maneuver.

The CHAIRMAN. What is the source of this debris?

Mr. BRIDENSTINE. So there is a lot of reasons for it. You know, there is a lot of commercial activity in space right now, which we fully, fully support. We have got to be able to use space for all of its benefits for humanity. And a lot of that commercial activity is launching, you know, low Earth orbit remote sensing satellites, low Earth orbit communications satellites.

Low Earth orbit is tremendously valuable for communications because its low latency and so the types of signals that you can use and the standards that you use are more like a cell phone technology. Whereas when you think about geostationary orbit, which is very far from Earth, you have to use different protocols.

So low Earth orbit is where all of these constellations want to be. The challenge is we don't have, as a Nation or even as a world, a robust architecture for how we are going to integrate all of these

capabilities into this small space. And it is becoming more and more of a problem. The President signed—

The CHAIRMAN. It is not a small space, but it is a finite—

Mr. BRIDENSTINE. It is. And the challenge is the probabilities of impact are measured—based on the amount of data that we receive, the probabilities of impact are measured in, you know, 1 in 1,000 chances, 1 in 5,000 chances, 1 in 10,000 chances. And for us as an agency with the International Space Station, which is \$100 billion investment, we take those probabilities and we say, OK, we need to maneuver. But if we are—

The CHAIRMAN. Are these functioning objects or are they junk? When I hear debris, I think of something left over from something in the past.

Mr. BRIDENSTINE. Yes, sir. So this object that we had to maneuver for just a few days ago is unidentified. We don't know what it is. We don't know where it came from. It is not something that is operated by—it is junk. It is literally junk in space.

Now, there are also satellites that have become debris because they just came to the end of their useful lives and they don't they don't deorbit themselves. They will over a number of years, but they are still there now. And then we also have just a lot more activity from our international friends, if you will. And they don't necessarily all follow the debris mitigation guidelines established by NASA and supported by the U.S. Government.

The CHAIRMAN. So there is no international protocol yet on space debris?

Mr. BRIDENSTINE. What we have is we have international guidelines that NASA creates, the U.S. Government adopts and then those get adopted, you know, at the U.N. and other places. The question is, what are we doing to make sure that people adhere to those guidelines? Anybody can say they follow them. But the question is, how do you follow up and make sure that they actually are? And how do you prove that they are not, if they are not?

The CHAIRMAN. So there are guidelines that have been developed by the United States and have been adopted by the United Nations?

Mr. BRIDENSTINE. Yes. And in fact—

The CHAIRMAN. The individual countries didn't need to sign on? Is that ideal?

Mr. BRIDENSTINE. Well, yes. I mean, it is better that they sign on than not sign on. But a lot of countries sign on and then they don't fully adhere to those principles.

The CHAIRMAN. OK, well, just one other thing and then I will recognize Senator Gardner. He is in the queue. The Department of Commerce intends to or has taken over the space situational awareness mission for civil and commercial entities. Do you support that? And how would authorizing the Office of Space Commerce to take over this function from DOD be helpful?

Mr. BRIDENSTINE. A couple of things. Right now you have the Department of Defense that is responsible for fighting and winning wars in space now with the Space Force and U.S. Space Command, the challenge is we are having them at the combined space operations center. We are having them operate as though they are the FAA for space. So they are doing conjunction analysis and warning

for all of the commercial activities in space. They are doing it for all of the international activities in space. And all of those international and commercial folks that are using that facility, that capability, they are not paying for it.

So we are providing basically global space situational awareness and space traffic management to the world for free. In order to relieve them of that duty, we need to have—this is just think about the 1950s. You know, we had the Department of Defense responsible for air traffic control throughout the Nation. Now, it wasn't as crowded back then, but there came a time in 1958 when President Eisenhower said, you know, we are done with this because there are too many midair collisions. He said we are done with this.

We need a civilian agency that can do this activity. We are now there for space right now. So we need to take the unclassified data from the combined space operations center. We need to flow that to the Department of Commerce. And we need to combine that data with commercial—it is all about data. It is about quantity and quality of data.

We need to take that data, combine it with commercial and international data to create a single integrated space picture that can be shared with the world. And by the way, the world needs to support us in that effort. So if we are doing space situational awareness and space traffic management, and the rest of the world is not, that creates a big problem.

The CHAIRMAN. Is there broad consensus within the Administration for this move?

Mr. BRIDENSTINE. Yes, sir, 100 percent.

The CHAIRMAN. And it is being done administratively, I understand.

Mr. BRIDENSTINE. Well, when you say administratively, right now, these activities are being done by the Department of Defense. The challenge right now is the Department of Commerce, under an executive order, basically a space policy directive three from the President, the Department of Commerce should be picking up these missions, but they haven't been—they don't have the authorities provided by Congress at this point, nor do they have the appropriations provided by Congress. And so we are kind of in limbo right now.

The CHAIRMAN. So you need the appropriators to address this issue and hopefully late in the year or early next year, and this needs to be a provision in the next authorization bill. Is that correct?

Mr. BRIDENSTINE. I would be very supportive of that.

The CHAIRMAN. Thank you very much. Senator Gardner.

**STATEMENT OF HON. CORY GARDNER,
U.S. SENATOR FROM COLORADO**

Senator GARDNER. Thank you, Mr. Chairman, and thank you, Administrator Bridenstine, for your service and all the work that you do for NASA and our aerospace companies in Colorado and beyond. It is imperative that we preserve America's leadership in innovation and science, particularly in space. And we certainly know our adversaries are working very diligently to undermine our lead-

ership, and our space for programs, obviously, continue to be the envy of the world. And nations like China and others are trying to steal our ingenuity and displace U.S. leadership.

Mr. Chairman, I would like to enter into the record a CNBC global CFO council article dated March 1, 2019, entitled “One in Five Corporations Say China Has Stolen Their IP Within the Last Year.” I would also like to enter a May 12, 2020 space news article entitled “Space Force Vice Commander: China Can’t be Allowed to Buy Bankrupt U.S. Space Companies,” which highlights concerns raised by Lieutenant General David Thompson regarding how Chinese interest may seek to invest in companies being squeezed by the COVID 19 pandemic.

Finally, I would like to enter into a record a Reuters article dated September 15 entitled, “Exclusive, White House Asks U.S. Agencies to Detail All China Related Funding,” which outlines a request by the Office of Management and Budget to understand how funding may be aiding China in unintended ways. Look, we know that Chinese actors are stealing intellectual property from American businesses. We know that they are using their corporate social credit system in a very worrisome way and that many of the criteria of this system envisions that it could be used to require the transfer of technology or make it easier for Chinese interests to steal American intellectual property.

A report from the Commission on Theft of American Intellectual Property estimates that China steals up to \$600 billion worth of American intellectual property every year. Put that into perspective, every single year China is stealing property from the United States worth nearly three times the size of the entire GDP of the Nation of Portugal.

That threat is—that theft is enabled in part through China’s Internet security law, which was implemented back in 2017, which allows them to review sensitive company information that puts IP and human rights equally at risk. But it is not just this misguided law or China’s unyielding quest to upend freedoms of all kinds around the globe. Without someone to step in and stop them, China thinks they will get away with this kind of behavior. Administrator Bridenstine, do you agree that China has a clear history of stealing American intellectual property?

The CHAIRMAN. Senator Gardner, you asked for three items to be admitted into the record—.

Senator GARDNER. Yes, correct.

The CHAIRMAN. Without objection, that will be done.

[The information referred to follows:]

FOUNDING MEMBERS | CNBC CFO COUNCIL

THE BOTTOM LINE

1 IN 5 CORPORATIONS SAY CHINA HAS STOLEN THEIR IP WITHIN THE LAST YEAR:
CNBC CFO SURVEY

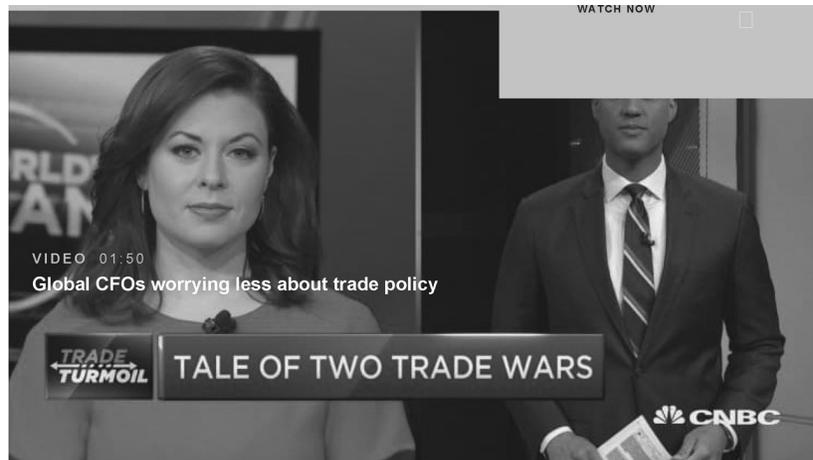
PUBLISHED FRI, MAR 1 2019 5:00 AM EST | UPDATED FRI, MAR 1 2019 10:21 AM EST

Eric Rosenbaum@ERPROSE

KEY POINTS

- Theft of intellectual property by Chinese companies is a major point of contention between the Trump administration and Chinese government.

- Just under one-third of CFOs of North America-based companies on the CNBC Global CFO Council say Chinese firms have stolen from them at some point during the past decade.
- U.S. trade policy remains a negative for businesses around the world, but right now European CFOs are expressing the biggest concerns about trade policy as an external risk factor.



As President Donald Trump says his administration is moving closer to a trade deal with China, one of the major sticking points has been China's disregard of *intellectual property* protections and claims dating back years about rampant Chinese theft of corporate trade secrets. The allegations are not hyperbole.

One in five North American-based corporations on the CNBC Global CFO Council says Chinese companies have stolen their intellectual property within the last year. In all, 7 of the 23 companies surveyed say that Chinese firms have stolen from them over the past decade.

As the *Trump* administration works on a trade deal with *China* and hundreds of billions in potential tariffs loom if a deal can't be reached—Trump has delayed the tariffs scheduled for Mar. 1 based on “significant progress” he said is being made—the issue of IP theft has been a huge sticking point.

The *CNBC Global CFO Council* represents some of the largest public and private companies in the world, collectively managing nearly \$5 trillion in market value across a wide variety of sectors. The survey was conducted between Feb. 7 and Feb. 22 among 54 members of the council located across the globe, including the subset of North America-based chief financial officers.

One of the bigger grievances that led to recent US-China trade negotiations has been U.S. accusations of Chinese companies stealing IP from U.S. companies. Has your company been the victim of such a theft in the recent past?

Hardline Trump *U.S. Trade Representative Robert Lighthizer* said on *Wednesday* in testimony on Capitol Hill that a deal with China must not only include more Chinese purchases of U.S. products but enforcement. There have been recent reports that Lighthizer is unhappy with Trump's willingness to make a deal with the Chinese without extracting strong enough terms. White House officials have downplayed the reported tensions.

“We can compete with anyone in the world, but we must have rule, enforced rules, that make sure market outcomes and not state capitalism and technology theft determine winners,” Lighthizer said in testimony to the House Ways and Means Committee on Wednesday.

“Let me be clear,” Lighthizer testified. “Much still needs to be done both before an agreement is reached and, more importantly, after it is reached, if one is reached.”

After the December G20 meeting in Buenos Aires, Argentina, China took a step that conservative think tank American Enterprise Institute—which for years has been sounding alarms about IP theft by China—described as significant, when the Chinese government issued a memo that set out some *38 punishments* for IP violators, including denial of access to government funding.

“The mere publication of the memo (which explicitly referred to American complaints) was an important concession: Until quite recently the Chinese government had officially *denied* that significant IP theft occurred in China,” AET’s Claude Barfield wrote in a blog post. But the issues are complicated by, among other things, blurred lines between cyber espionage committed *by the Chinese government against corporate and military targets* and the passing on of those secrets to Chinese companies.



U.S. President Donald Trump, U.S. Secretary of State Mike Pompeo and members of their delegation hold a dinner meeting with Chinese President Xi Jinping, Chinese Foreign Affairs Minister Wang Yi and Chinese government representatives at the end of a G-20 summit in Buenos Aires, on Dec. 01, 2018.

Saul Loeb | AFP | Getty Images

There are no exact statistics on trade secret theft ranked by nation, but China remains the world’s principal IP infringer across all types of IP theft, according to a spokesman for the IP Commission, which estimates up \$600 billion annually in cost to the U.S. economy from these actions. The IP commission noted that Chinese citizens are prosecuted most frequently in U.S. courts for trade secret theft.

Cases of IP theft in recent years brought by the U.S. government against Chinese employees of U.S. firms and Chinese intelligence officers have involved large companies including *Apple, IBM* and *GE*.

Trade policy is now the biggest issue in Europe

North American-based companies are less concerned that they have been in recent quarters about the impact of U.S. trade policy on their business. Only 17 percent said uncertainty surrounding trade policy would hurt their companies ability to make long-term investments. Eighty-three percent indicated that tax reform and eased regulations outweigh any ongoing trade issues. CFOs across the globe also remain *confident that the U.S. economy will not face a recession in 2019*—not a single North America-based CFO taking the survey thinks there is a risk of recession this year.

But in Europe, where trade tensions between the U.S. and EU countries have been rising, the risks from U.S. trade policy are becoming more prominent. U.S. trade policy was the No. 1 external risk factor cited by CFOs from the Europe, Middle East and Africa region taking the survey, with 35 percent saying it was the biggest current threat to their business. That was higher than the percentage of CFOs from the Asia-Pacific region citing trade policy as the biggest external risk (29 percent). Only 17 percent of North America-based CFOs cited trade policy—concern about consumer demand was cited by many more CFOs from the U.S. (43 percent).

Across the total of 54 CFOs included in the Q1 CNBC Global CFO Council survey, consumer demand was cited as the No. 1 external risk factor (28 percent). Meanwhile, U.S. trade policy fell from No. 1 in the fourth quarter of 2018 to No. 2, with 26 percent of global CFOs citing it as the biggest external risk.

U.S. trade policy remains far from a positive contributor to business outlook even as it slipped from the top spot among risk factors. CFOs across the globe overwhelmingly say its impact will be negative over the next six months, but the sever-

ity of that view declined from the fourth quarter of 2018 (when 73 percent of CFOs said it would be negative) to the Q1 survey (63 percent).

SPACENEWS

SPACE FORCE VICE COMMANDER: CHINA CAN'T BE ALLOWED TO BUY BANKRUPT U.S. SPACE COMPANIES

Lt. Gen. Thompson: DoD is working with the White House and plans to work with Congress to help space companies that face bankruptcy.

Sandra Erwin May 12, 2020



Arianespace conducted its third launch for OneWeb March 21 from the Baikonur Cosmodrome in Kazakhstan. Credit: CC Yuzhny/Roscosmos.

WASHINGTON—If the Chinese government made a move to buy the assets of the *bankrupt space internet company* OneWeb, could the U.S. Space Force do anything to stop it?

That question was posed to Lt. Gen. David Thompson, vice commander of the U.S. Space Force, during an online interview May 12 with retired Lt. Gen. David Deptula, dean of the Air Force Association's Mitchell Institute for Aerospace Studies.

Thompson did not comment on any specific actions that DoD might take regarding OneWeb. The company's assets are up for grabs after it filed for bankruptcy on March 27, becoming a poster child for the space industry's COVID-19 financial setbacks.

He said DoD is working with the White House and plans to work with Congress “not just focused on OneWeb but on all of the commercial space companies that face bankruptcy and face those concerns. We want to see what we can do in terms of securing the capabilities we need for national security, number one, and ensuring that our adversaries don't have the opportunity to acquire those capabilities.”

Deptula pointed out that the U.S. military was counting on OneWeb to provide satellite-based broadband communications in the Arctic, an area of the world where China plans to grow its influence. Before going out of business, OneWeb launched 74 high-speed broadband satellites into orbit.

As venture capital has retreated from the space sector during the pandemic, the *Pentagon has raised concerns* that China could move in to acquire distressed companies that have technologies relevant to national security. The Pentagon has not explained how it could stop Chinese acquisitions but officials have indicated that they are paying close attention to the space sector partly for that reason.

Thompson mentioned the work of the Space Acquisition Council—a new organization created by Congress that includes the senior leadership of the Department of Defense, the U.S. Air Force and Space Force, and the intelligence community. The council in recent weeks has held emergency meetings to discuss options to help the commercial space industry and protect national security capabilities.

The council “recognized that what they really needed to do quickly was consider the threat that this virus posed to commercial space, to smaller space companies in the commercial and national security sectors and what they might do about it,” said Thompson.

He said one of the topics that will be discussed with Congress is what investments could be made quickly to “provide capabilities we know we need, in areas we need to be more aggressive that are also going to help the commercial and national security space sector.”

According to the British newspaper *The Telegraph*, two firms with links to the Chinese government have submitted proposals to buy some of OneWeb’s assets. The paper also reported that OneWeb has approached DoD about a possible support package to help ward off the Chinese.

Sandra Erwin

Sandra Erwin writes about military space programs, policy, technology and the industry that supports this sector. She has covered the military, the Pentagon, Congress and the defense industry for nearly two decades as editor of NDIA’s National Defense. . .

REUTERS—MONEY NEWS SEPTEMBER 4, 2020/6:10 AM/UPDATED 3 YEARS AGO

EXCLUSIVE: WHITE HOUSE ASKS U.S. AGENCIES TO DETAIL
ALL CHINA-RELATED FUNDING

By David Shepardson

WASHINGTON (Reuters)—The White House has asked U.S. government agencies for extensive details of any funding that seeks to counter China’s global influence and business practices, or supports Beijing, amid growing tensions between Washington and Beijing.



FILE PHOTO: Chinese and U.S. flags flutter near The Bund, before U.S. trade delegation meet their Chinese counterparts for talks in Shanghai, China July 30, 2019. REUTERS/Aly Song/File Photo

According to an Aug. 27 White House Office of Management and Budget (OMB) document seen by Reuters, the OMB directed U.S. agencies to submit “cross-cutting data on Federal funding that aids or supports China, or that directly or indirectly counters China’s unfair competition and malign activities and influence globally.”

China denies it engages in unfair competitive practices.

The document, titled “Strategic Competition with China Crosscut,” does not say how the information will be used other than that it will “inform policymakers” of the myriad ways U.S. government spending involves China.

The United States and China have grown antagonistic toward each other with disagreements that stretch from a two-year-old trade war, to the Trump administration blaming Beijing for a lack of transparency about the spread of COVID-19.

The sweeping budget data request will be used to help policymakers and notes all funding should “reflect strategic priorities” when responding to China.

Some U.S. programs and spending under review dates back a decade or more. The document directs Federal agencies to respond by Sept. 21.

A spokesman for OMB confirmed the agency effort, telling Reuters that “to ensure that the United States remains strong and in a position of strength against rival nations like China, OMB has asked Federal agencies for all funding meant to counter China, or which could aid China.”

The memo includes instructions on how to submit both classified and unclassified U.S. spending details and seeks details of all U.S. government funding directed for spending inside China.

The White House document asks for data for all U.S. government funding used to “counter malign Chinese influence or behavior incongruent with American interests.”

It cites as examples “funding for programming to counter the One Belt One Road (OBOR) or Belt and Road Initiative (BRI); funding for military operations, equipment and infrastructure, the primary purpose of which is to deter aggressive Chinese behavior.”

It also seeks details of “secondary” U.S. efforts on China like “marginal contributions which were necessary to maintain a U.S. lead over China in terms of voting power within key international organizations” and funding for other U.S. efforts.

The document also seeks data on U.S. government funding for programs whose primary purpose is to counter Chinese technological prowess in key sectors like 5G and wireless communications, semiconductors, artificial intelligence and machine learning, quantum computing, cyber and system security, advanced manufacturing and robotics, autonomous and electric vehicles, biotechnology, advanced energy, and space technologies.

The White House sought details of spending on technical assistance from U.S. government experts, bilateral funding for the U.S.-China Clean Energy Research center and any other U.S. bilateral economic assistance programs.

It also seeks data on “HHS (Health and Human Services) funding for CDC (Centers for Disease Control and Prevention), NIH (National Institutes of Health) and other programming in China.”

The request also seeks details on any spending that “would overall contribute to Chinese GDP or technical capacities, including to Chinese government or military entities, State-owned commercial or industrial entities and entities functionally directed by” Chinese government leadership as well as grants or credit provided by U.S. supported international organizations.

Agencies must submit data on 2019 and 2020 budgets enacted into law, the 2021 Trump budget proposal and 2022 agency budget requests.

The budget review is just the latest effort that could lead to more actions against China.

Last week the United States blacklisted 24 Chinese companies and targeted individuals it said were part of construction and military actions in the South China Sea, the first such U.S. sanctions move against Beijing over the disputed strategic waterway.

Senator GARDNER. Thank you. Administrator Bridenstine, do you agree that China has a clear history of stealing American intellectual property?

Mr. BRIDENSTINE. There is no question.

Senator GARDNER. And the Reuters story that the Chairman kindly entered into the record there regarding OMB’s request to Federal agencies, I would like to share a quote from the article which reads, “a spokesman for OMB confirmed that agency effort

telling Reuters that to ensure the U.S. remains strong and in a position of strength against rival nations like China, OMB has asked Federal agencies for all funding meant to counter China or which could aid China.” Do you share the White House’s concern and belief that we should be taking a hard look at how our efforts at the Federal level could be benefiting China?

Mr. BRIDENSTINE. Yes.

Senator GARDNER. Do you agree we should be concerned with potential Chinese interest seeking to invest in U.S. companies and what that could mean to our economic and national security?

Mr. BRIDENSTINE. Yes.

Senator GARDNER. Given your answers to those questions, do you agree it only makes sense for NASA to consider Chinese investment as part of its contracting process?

Mr. BRIDENSTINE. Yes. I think the answer is absolutely 100 percent, yes. And just so you know, we are grateful for your leadership on this. I can tell you are very passionate. I would also say how that is done really matters to NASA. What we have to do as an agency is make sure that we don’t put ourselves in the role of CFIUS or we don’t put ourselves in the role of the Department of Justice or the FBI.

We have to be really careful that we do the things that we are good at like getting to the moon and onto Mars. We have to be careful about how—100 percent agree with everything you just said, but we are not really an investigative agency, so we need to be careful about how we go about doing this.

Senator GARDNER. Well, I just want to make sure that we are investigating Chinese investments into U.S. aerospace companies and making sure that we are treating NASA as important to this issue as we are TikTok, with Chinese investments and concerns.

I would think that our aerospace, national security space interests, Space Force, Space Command and NASA are equally important. That we give the attention to that with China, in regards to China as we do to TikTok with China. Administrator Bridenstine, thank you. Mr. Chairman, thank you for your time.

The CHAIRMAN. Well, thank you very much, Senator Gardner. Let me say, there are no other Senators in line. I have another question, but a note. A number of offices are listening, and if members of the Committee intend to ask questions, they should let us know, because if not, this may be the last round of questioning.

Mr. Administrator, let’s talk about the enhanced upper stage, EUS or Block B. The enhanced upper stage will allow NASA to make full use of the SLS. I am concerned that the budget request defers funding to develop this. How necessary is this and what suggestion do you have for the Senate and the House?

Mr. BRIDENSTINE. Yes, sir. So to start, because Congress and the Senate have fully funded all of our activities for the exploration upper stage—just so you know, those activities are underway, and we are, you know, getting to the point now where we have got, you know, key decision point C or, you know, critical design review right in front of us. So all of this to say that—

The CHAIRMAN. We are talking enhanced upper stage.

Mr. BRIDENSTINE. Yes, sir. Yes.

The CHAIRMAN. Alright.

Mr. BRIDENSTINE. Well, EUS, some people call it enhanced, some people call it exploration upper stage, but we are talking about the same.

The CHAIRMAN. Good. Just want to make clear.

Mr. BRIDENSTINE. And so, to the extent that we have an exploration upper stage or an enhanced upper stage, that would be gratefully beneficial to the agency and we can use it. And so that is important to note. It is also true that when we go to the moon by 2024 with Artemis 3, we are going to be going with what is called an interim cryogenic propulsion stage, ICPS.

That ICPS is already—you know, it is a system that is in place that we can use and will get us to the moon by 2024. When we think about what happens beyond that, depending on if the Senate and the House make it available to us, we can certainly use the exploration upper stage or the enhanced upper stage. At this point, we think that there are opportunities to use commercial vehicles potentially in the future. But of course, all options are, you know, should be considered.

The CHAIRMAN. Thank you. Senator Udall is next.

**STATEMENT OF HON. TOM UDALL,
U.S. SENATOR FROM NEW MEXICO**

Senator UDALL. OK. You got me there?

The CHAIRMAN. We can hear you. We can hear you well.

Senator UDALL. OK. Thank you, Mr. Chairman, for the recognition, and let me welcome the Administrator here. I remember having a good conversation with him when he came through so good to see you. Satellite servicing and debris removal will become an increasingly important part of space operations as low Earth orbit and other heavily populated orbits become increasingly congested by small satellites.

Last October, I introduced Senate Resolution 386, a resolution supporting improvements in space, situational awareness, and advances in technology, and calling for international cooperation to address the increasing dangerous of space debris. Do you support the kind of improvements to and advancements in situational awareness technology called for in my resolution?

Mr. BRIDENSTINE. Yes, sir, without question. The challenge that we have as an agency—not as an agency, but as a Federal Government is data. And so we need the ability to get as much information on the debris that is in low Earth orbit as possible to keep our missions safe. Yes, sir. We need new, more, and better technology and data.

Senator UDALL. Appreciate that answer. How important is it to ensure international cooperation on this issue and implement the 21 guidelines for space sustainability agreed to by the United Nations Committee on Peaceful Uses of Outer Space?

Mr. BRIDENSTINE. So without international support, you know, we end up, you know, not getting the results that we are going to need. So without question, the United States of America is the pre-eminent space nation, but others are very rapidly developing and deploying space assets and creating debris that needs to be dealt with. So I am very supportive of international agreements that

mitigate the debris. And, of course, international agreements that enable us to see and respond to the debris as well.

Senator UDALL. Thank you for that answer. New Mexico's space industry is growing rapidly. Companies such as Virgin Galactic, SpinLaunch, and Up Aerospace call New Mexico home. And I am glad to hear that NASA is beginning to partner with some of these commercial spaceflight companies as well as others. Besides using these commercial space entities to eventually take individuals to the International Space Station and conduct their training for NASA personnel, is this an opportunity for NASA to increase other experiments and tests conducted from places like Spaceport America in New Mexico? And if so, what sort of experiments and testing would NASA conduct?

Mr. BRIDENSTINE. Yes, sir, we do these activities through what we call the Flight Opportunities Program, which is resident in the Space Technology Mission Directorate at NASA. That Flight Opportunities Program has already conducted, I think it is over 700 different experiments and technology demonstrations using commercial suborbital vehicles, everything from vertical takeoff and landing, using rockets to horizontal takeoff and landing using rockets, but also high altitude balloons.

And so we have done hundreds of these kind of experiments and there are huge opportunities in front of us. So the value is, if you are trying to get access to microgravity, there is really only a couple of ways to do it. One is, you know, a drop tower. You drop something, you know, from the top of a building and you have got a second or two of microgravity. After that, we have parabolic flight where you take an airplane and you put it on a parabolic trajectory and you can get 20 to 30 seconds of microgravity.

After that, you have to fly all the way to the International Space Station, which is, you know, tens of millions of dollars and, of course, very challenging. It takes years of training, for example. But that commercial suborbital capability that you just mentioned gives us a great opportunity to do experiments for 5 or 10 minutes in microgravity, which is a lot more than the 20 or 30 seconds we can get from a parabolic flight. What does that mean? We can test things. You ask what kind of things we could test.

Well, right now we have been using it to prove that we can do 3-D printing in microgravity, which is very difficult, but it can be done and we are proving that, that we can create the technologies capable of doing that. 3D printing is hugely valuable when you do spaceflight because you want to take as few things as possible but be able to make things in space. We think about cryogenic management. How do fluids move in a microgravity kind of environment? So we use these kind of 5 or 10 minute flights for those types of activities. Fluids are critically important to spaceflight and different fluids operate very differently in microgravity.

Understanding that is necessary as we progress in our missions and not having to fly those kind of experiments all the way to the International Space Station is hugely valuable to the taxpayer of the United States of America. You know, there are other experiments that we do. We are looking at—in fact, right now, for the first time, one of my initial initiatives as the NASA Administrator was what about human tended payloads?

A lot of these experiments are conducted by university researchers or private institutions, and some of them wanted human tended payloads. Well, we now have an opportunity to accept human tended payloads. Wouldn't be NASA astronauts, but they would be commercial, suborbital scientists or researchers that can fly on these commercial vehicles funded by NASA. So that is a huge development that we have just put forward.

And I think eventually we are going to be able to use these vehicles to, in fact, fly American astronauts as well for training and experiments and other capabilities. So I really think, Senator Udall, there is a great future here with commercial suborbital vehicles.

Senator UDALL. Thank you, Mr. Administrator, for that excellent answer, and good to see the good work you are doing over there at NASA. I yield back, Mr. Chairman.

Mr. BRIDENSTINE. Thank you, sir.

The CHAIRMAN. I think the bipartisan sentiment expressed by Senator Udall is widely shared. Senator Capito.

**STATEMENT OF HON. SHELLEY MOORE CAPITO,
U.S. SENATOR FROM WEST VIRGINIA**

Senator CAPITO. Thank you, Mr. Chairman. And Administrator Bridenstine, it is nice to see you again, however remotely. I really enjoyed your visit to West Virginia when we renamed the IV&V Center for West Virginian's own Katherine Johnson. She has since passed away since we met and she was quite a pioneer. So the 700 jobs across the state that NASA has and the billions of dollars of economic output of NASA was really—great partnerships all throughout our state, particularly in the regions that we were in.

I would like to ask a quick question. It is more on the appropriations side that—you know, I support NASA leveraging innovation and investment that you all bring about. But it seems that NASA's plan to develop a moon lander differs from the usual contracting approach that NASA has taken and has used on development of other major programs and spacecraft. I wonder if you could talk about that. Have you found it beneficial, and how is that rolled out?

Mr. BRIDENSTINE. Yes, ma'am. It is a critically important question. When we think about these successes that we have had with the Commercial Crew program, for example, which we just saw—you know, we launched our American astronauts on a commercial vehicle, which was fantastic. The goal that we have in that activity, as well as commercial resupply of the International Space Station, the goal that we have is ultimately for NASA to be one customer of many customers in a very robust commercial marketplace for human activities in low Earth orbit.

But also we want to have numerous suppliers that are competing against each other on cost and on innovation and on safety. And we have achieved that with Commercial Resupply, now, Commercial Crew. We also want to start now Commercial Habitation. So commercial space stations themselves.

So this is kind of the progression. The question that we had to answer was, given all of the programs that NASA has had in its history, if we are going to go to the moon as quickly as possible, how do we want to organize our efforts? And the decision that we

made was we are going to model this after Commercial Resupply and Commercial Crew. And so we said, we are going to partner with commercial industry to go sustainably to the moon, again with the intent that they get customers, maybe not initially but eventually, that are not NASA and where they are competing against each other on cost and innovation and on safety.

And if we can do that, we can drive down costs, we can increase access. We can we can have sustainability at the moon, which the Apollo program never delivered on. And that is ultimately our goal. Our goal is to figure out how do we have a program where we go to the moon and stay. And that commercial capability is ultimately what we think is a big part of that success that we are going to see in the future.

Senator CAPITO. So in the initial—in the phase in which you are in right now, are you finding this there are those private and commercial entities that want to join the space, that there is enough to provide for competition? Or is this something that maybe our educational institutions and other private businesses could be developing toward? What are you finding in that space?

Mr. BRIDENSTINE. So right now, ma'am, we had initially, when we did this program to start, we had five proposals and a number of those proposals had large capital investments behind them from the private sector already. So I think that there is lots of capability here already. We have selected three of those five proposals.

And then, of course, we are grateful for the funding that we got from the House and the Senate for what we call the base period. So now we have got three commercial lunar landers under development right now in the base period which ends in February 2021. And then from that point in February, we are going to make a determination whether or not there is one, two, or even three of those companies that we believe can get to the moon as soon as 2024. And so I would say, yes, ma'am, we have had a lot of support from private industry for this activity.

Senator CAPITO. Good. I introduced with the Senator Sinema the 21st Century Space Grant Modernization Act, which is included in the reauthorization that passed. And I think you and I have talked about how the space grant program really benefits people all across this country. Have you had any stops and starts during the COVID era with this? Are you still processing their proposals in a timely fashion, and what are the steps of that program?

Mr. BRIDENSTINE. So as of right now, ma'am, we are OK. But it is going to be more challenging as time goes on for sure. So we provide grants to universities for them to deliver on specific tasking. And, of course, universities are having challenges delivering on that tasking, the same as NASA, when we do things at our centers. If we have, you know, an outbreak at a center, our people can't go to work anymore than the people at a university can go to work. So this is a nationwide challenge that we are going to have to deal with.

So there is a day in the future when we are going to have to make tough decisions. And those decisions are going to be maybe we don't start a new project and we use the funding that we receive for the continuation of the projects that have fallen behind.

Or we are going to have to come back to the House and the Senate and request additional appropriations in order to do the new starts.

So I want to be clear, there is an impact from COVID. We have been successful as an agency moving forward with missions that we call essential, and now we are opening up very rapidly missions that we call mission critical functions, which would have an impact to the agency, but they are not quite as high of an urgency as mission essential functions. But there will be an impact for a lot of missions that are not in those two categories. And a lot of those early technology readiness level capabilities that universities are involved in are going to see challenges.

Senator CAPITO. Thank you. Thank you. I yield back. Thank you.
The CHAIRMAN. Thank you, Senator Capito. Senator Peters.

**STATEMENT OF HON. GARY PETERS,
U.S. SENATOR FROM MICHIGAN**

Senator PETERS. Thank you, Mr. Chairman. And Administrator Bridenstine, good to have you here and hear your testimony. Congress just recently passed a bipartisan PROSWIFT Act that I authored with Senator Gardner to better predict and mitigate the threats of the geomagnetic storms and other space weather. And if the COVID 19 pandemic has taught us anything, that we need to be prepared for disruptions that can upend our economy in a significant way.

And Administrator, I know that you are the author of a similar bill when you were serving in the House. So I know you can talk quite a bit about this topic. And just would like to get your sense of your concern about impacts of space weather and what they can have on everyday lives and the significant threat that they pose, and why this legislation is important, why you authored it in the House, and now that it is passed into law, what can we expect?

Mr. BRIDENSTINE. Yes, sir. Senator Peters, you and Senator Gardner should be absolutely commended for leading on this issue. You know, I was happy to support it in the House when I was there, but certainly without your leadership, it would not have happened. And working on it for all of these years from 2015, finally getting it done. I know that wasn't easy. But this is going to have huge impacts for America's human spaceflight capability. We think about the Artemis program and going to the moon. We are building a space station called Gateway. It is a small space station around the moon for—and in order to enable the reusability of human landers.

But we think about Buzz Aldrin and Neil Armstrong on the surface of the moon in 1969. Had they been there longer than they were, they would have been hit with a solar flare from the sun. And that would have damaged them, and in fact, could have very well ended their lives early. But we didn't know that back then. Now we do know that. So understanding the sun, the solar winds, solar radiation, we think about coronal mass ejections and solar flares, these are things that we have to understand very well if we are going to have a sustainable presence beyond the Van Allen radiation belts.

And that is our goal. We want to explore space. And this bill is going to go a long ways to enabling us to have the early warning

that we need and to be able to do the research necessary to even predict, to warn people based on the prediction not just the detection of those kind of activities.

Senator PETERS. As the Ranking Member of the Armed Services Emerging Threats subcommittee, I was pleased to see in the Memorandum of Understanding announced last week that General Raymond and the Space Force that highlighted the importance of completing the survey of near Earth objects. These hazardous objects impact the Earth, as you know, and pose a threat to our safety, security, and to our military. The NASA Reauthorization Act of 2019 includes an amendment that I authored to direct the Secretary of Defense to support NASA's work in the area.

And the importance of this was highlighted with the discovery of Comet NEOWISE earlier this year, which was previously unknown. Can you talk briefly about the importance of completing the survey of hazardous objects, something that Americans consistently list as a top priority for NASA, and how the Department of Defense can help, particularly with respect to the deployment of a new space based telescope to better track these threats?

Mr. BRIDENSTINE. Yes, sir. Again, critically important to the Nation and the world, in fact. You know, I have often said and others have said, you know, the dinosaurs didn't have a space program and it didn't help them. So we think back to 2013 was my first year in the House of Representatives and we saw the Chelyabinsk incident where we had this asteroid come in and explode over Russia. And while it didn't kill anybody that we know of, it resulted in over 1,000 people going to the hospital and broken windows and damaged buildings. And that was that was an asteroid. I don't remember how big it was, but it was on the something like 30 meters big in diameter. So we think about that incident. Then we think about how those incidents happened throughout history. There have been other incidents.

So in the early 1900s, there was an incident that took out like 800 square miles in Russia, for example. So, yes, we need to be able to detect these objects. We need to make sure that we do have a near Earth objects surveillance mission, partnering with the United States Space Force. We are doing that already with the space surveillance telescope down in Australia, NASA and partnered with, at the time it was Air Force Base Command, to put our own algorithms into their mission.

Their mission, of course, is to detect nefarious activities in space. Our mission is to look for bolides in space. But we put our algorithms into their space telescope. It is now in Australia delivering great work for the Air Force or Space Force now. And we as an agency get to detect bolides. So that is a great partnership and extending that partnership into new domains would be—we would be very supportive of that.

Senator PETERS. Alright. Thank you for your testimony. I appreciate it.

Mr. BRIDENSTINE. Yes, sir. Thank you.

The CHAIRMAN. Thank you, Senator Peters. Senator Thune.

**STATEMENT OF HON. JOHN THUNE,
U.S. SENATOR FROM SOUTH DAKOTA**

Senator THUNE. Thank you, Mr. Chairman. Administrator Bridenstine, welcome to the Committee. Did you make your annual trek to South Dakota?

Mr. BRIDENSTINE. I have not. COVID might have gotten in the way of that one, but there will be another day.

Senator THUNE. Good. Well, and you are little busy and we appreciate that. The global space economy has greatly expanded over the last 10 years, meaning that United States leadership in space is more critical now than ever before. And I think, as you know, we have lots of discussions around here about allocation of tax dollars, how to get the best return, whether or not investments in some areas make sense.

So could you describe how the American taxpayer stands to benefit from continued investment in NASA missions and programs and what this investment means for job growth, technological advancement, and economic prosperity in the United States?

Mr. BRIDENSTINE. Yes, sir. So I will just start with maybe a little history here. When we think about the Apollo program, a lot of people didn't really know what was going to materialize from the Apollo program. But right now we are having a hearing and these cameras are on and people are watching all over the country using Direct TV or Dish Network or Internet broadband from space. They might be listening to it on the radio with XM Radio.

So these are communication capabilities born from this little agency called NASA, all tied to that early, you know, NASA era. We think about how we navigate with GPS and how that has fundamentally transformed the American economy. We think about precision agriculture, critically important to South Dakota, for example. We are using space assets right now in order to sense the Earth and every part of the electromagnetic spectrum and make determinations as to how can we increase crop yields while reducing water usage by as much as 25 percent.

And so that is going to feed more of the world than ever before. So how we produce food, how we produce energy cleanly so that, you know, pipe pipelines, we can detect leaks early, shut those leaks down for, you know, greenhouse gases so that energy companies don't get fined by the EPA, for example.

So NASA is playing a role there. The way we do disaster relief is dependent on a lot of these technologies that NASA has developed. We don't do disaster relief, but we have developed these technologies that have now been commercialized that the Government benefits from. We think about how we predict weather, how we understand climate and how it is changing, and, of course, national security and defense. So many capabilities that that NASA initiated have been utilized by the Department of Defense and vice versa.

If you go back in time, it was intercontinental ballistic missiles that first launched, for example, Alan Shepard, to space. So, I think these technology development programs have demonstrated that, you know, we really don't know at the end of the day where all of it goes, but we know this, the investment, the return on in-

vestment is huge. Now, those are things that we really can't measure.

But I hear a lot, as the NASA Administrator, I hear about Tang and Velcro, for example, because of the Apollo program and how those were, you know, I guess, very nostalgic kind of capabilities that were promoted in the Apollo era. But it goes so far beyond that. But we did an economic impact study because I wanted to understand what is the impact, and disregarding everything I just mentioned, just the direct economic impact to the United States for the year 2019 was \$64 billion.

And it was 312,000 jobs in the United States of America, you know, directly impacted from NASA investments and capabilities. So all of that, I think, is tremendously valuable. And I think, if you want to get a very specific return on investment, it is very—it is hard to measure that. You know, we have been working remotely and I use this little camera that is in my cell phone. That camera was developed for a Mars mission in the 1990s, and then it was licensed by Nokia, for example, and put into a phone. And all of a sudden now everybody on the globe has these cell phones with cameras in them that are used to communicate all over the world.

And of course, that has been proven to be very valuable, during the COVID era especially. So I think the return that we get from NASA is overwhelming and well worth—sir, I think maybe sometimes it is missed by the public that we as an agency get about one third of 1 percent of the Federal budget, like less than half of 1 percent of the Federal budget. And the return on that has been just astonishing.

Senator THUNE. Indeed. And it is a long and a very good list and one that probably I guess a lot of us sometime don't appreciate just how much impact that has had. Very quickly, could you share any updates on the development of optical communication technologies at NASA and the potential of these innovations to improve the NASA missions in low Earth orbit and beyond?

Mr. BRIDENSTINE. Yes, sir. So optical communications, basically get a very high frequency, which means you can pack a lot more data so you get very high data rates, and optical communications, the spectrum is very narrow and so you are able to prevent jamming in ways that you can't do with radio communications. And you can actually communicate from a lot further away with larger data rates. So it focuses the energy specifically where you want the energy to go.

For example, when we communicate from Mars with a high aperture antenna, you know, it is hitting the entire Earth and a lot of the signal isn't hitting the Earth at all, which is just wasted energy. But if you can put it into optical communications and narrowly focus it, you can target not just the Earth, but you can target a very specific point on the Earth, maybe an area the size of the State of South Dakota, for example.

So optical communications have tremendously valuable impacts. Right now, we are partnering with the Space Force to do a laser communication technology demonstrator that they are going to fly on our behalf and we are going to use that kind of technology to communicate the great data and information that we get in future missions to Mars or other places in the solar system.

Senator THUNE. Thank you. Thank you, Mr. Chairman.
The CHAIRMAN. Thank you, Senator Thune. Senator Sinema.

**STATEMENT OF HON. KYRSTEN SINEMA,
U.S. SENATOR FROM ARIZONA**

Senator SINEMA. Well, thank you, Mr. Chairman. And thank you to our Administrator for testifying today. NASA partners with universities and those partnerships provide significant benefits both to NASA and to the universities. All three Arizona public universities, the University of Arizona, Arizona State University, and Northern Arizona University provide students with hands on STEM education and research opportunities thanks to the Space Grant Program and other NASA partnerships. For example, the University of Arizona is a leader on the OSIRIS-REx mission, which will bring the first asteroid sample to Earth.

And at ASU, the Psyche mission marks the first time a university has led a deep space NASA mission. Once the spacecraft launches in 2023 and arrives at the asteroid in 2030, the Psyche ASU team will be the first scientists to study an asteroid, which is remarkably similar to a planetary core. In the past, Administrator, you have testified to this committee that university led missions are more likely to be on schedule and under budget. I appreciate your continued support for these valuable NASA university partnerships. But just last week, I learned of some potential changes to the near Earth Object Surveillance Mission at the University of Arizona and that raises some important questions.

As you know, in 2005, Congress required NASA to discover 90 percent of near Earth objects 140 meters and larger by 2020. The University of Arizona's Dr. Amy Mainzer has been a leader on this issue for years and has led the precursor projects in this area. Three months ago, NASA approved an organizational plan that took Dr. Mainzer on the role of survey director for the surveillance mission. But last week, without any consultation, NASA decided to remove her from the survey director role and transfer the mission leadership to NASA's Jet Propulsion Laboratory Center. Could you explain this decision to transfer the mission leadership?

Mr. BRIDENSTINE. Yes. So thank you for the question, Senator Sinema. And I will say that I have been briefed on this. I can tell you that we are 100 percent committed to the Neo surveillance mission. And I can also tell you that Dr. Amy Mainzer is somebody that NASA highly regards. And she is in the lead on this project and she will be in the lead on this project, period. That is going to happen.

I will also say that I think the issue here was a communication error. And I would also say that, you know, Dr. Zurbuchen, and I know Dr. Zurbuchen has been working this issue. He is the head of the Science Mission Directorate at NASA. I will tell you, he is 100 percent committed to this mission and making sure that we get this organizational structure right. But I think this has—and I want to be really careful with what I say here. But I think this issue has been resolved and I think it has been resolved in a way that is very favorable to all parties. And just know that we want to make sure that we are getting this done right. And I will make

sure that Dr. Zurbuchen is in communications with your office regularly on this issue.

Senator SINEMA. I appreciate that very much, Administrator. We have not heard any information since last week clarifying this change. And of course, as you can imagine, we in Arizona are very interested in ensuring that the University of Arizona and Dr. Mainzer retain this position in this very important mission in partnership with NASA. So I will move on to my next question summit. Some in NASA have said that direct admissions need to be let out of NASA centers and not universities.

Now, we know that is not a statutory requirement and it appears to be inconsistent with the evidence that university led missions such as OSIRIS-REx have proven to be cost effective. Can you talk a little about your position? Should direct missions be led out of a NASA center or is university-led appropriate?

Mr. BRIDENSTINE. I think there is a lot of opportunities to have these missions led by universities. I think the two that you highlighted are perfect examples of missions that have been very successful from universities. And these are not small missions. We are talking about OSIRIS-REx, which for the first time—you know, we have never been able to orbit an object like OSIRIS-REx is now orbiting. It is an asteroid in deep space called Benu.

And in fact, we are going to do for the first time in American history, in October, we are going to go down and we are going to grab some material from Benu for the first time ever and bring that back to Earth. So an asteroid return mission and that mission, of course, is led by the University of Arizona. And then, of course, you mentioned Psyche, which is in the asteroid belt on the other side of Mars in front of Jupiter, but a huge steel ball that is likely to be a planetary core that came apart at some point.

And we have never been able to study a planetary core before and now we are going to be able to do it. And it is led by Arizona State University. These two missions, I think, are perfect examples of what can happen when you have the university lead. And I know you are very well aware of this and you are a champion of it. But when a university leads, you get the scientists and the engineers that are sitting side by side and making determinations. So NASA comes in and we say, hey, here is the budget and here is the schedule. What can you do? The universities propose and other nonprofit kind of research institutes they propose.

When NASA selects the university, you get the scientists, the engineers, and they are forced to make trades early in the process. And because of those trades, they are able to keep a schedule and they are able to keep budget. So the engineer says, well, you know, we are not going to be able to achieve this, what if we did this instead? And the scientists can say, well, that will result in our ability to collect the science instead of that science and evaluate it this way instead of that way.

And those trades made early in the process results in schedule and budget actually being maintained. And even better is that students get involved. And so graduate students, even undergraduate students. So it is really—it is Government, it is academia, and it is students that come together, make it happen, and keeps cost and schedule, and then you have students that are graduating with

hands on experience that is tremendously valuable for our agency and our partners to help us develop capabilities. So I am a huge advocate of enabling universities as much as possible.

Senator SINEMA. I appreciate that. Thank you, Administrator Bridenstine. And thank you, Mr. Chair. I yield back.

The CHAIRMAN. Thank you very much, Senator Sinema. Senator Sullivan is next.

**STATEMENT OF HON. DAN SULLIVAN,
U.S. SENATOR FROM ALASKA**

Senator SULLIVAN. Thank you. Thank you, Mr. Chairman. Can you hear me?

The CHAIRMAN. Yes. We can hear you.

Senator SULLIVAN. OK, great. Thank you, Mr. Chairman and Administrator Bridenstine. Thank you for your testimony. You know, one of the things that I wanted—and you know, you and I have talked about this quite a lot, but NASA’s history of inspiring Americans, particularly young Americans. And with the 50th anniversary of the Apollo mission last year, I think, which had a lot of inspirational moments, you know, I think you have read this book.

You and I talked about this *American Moonshot*, which is a great book by Douglas Brinkley on the Apollo missions. I actually think that with the work you are doing right now, the Artemis program, the work that other agencies, not other agencies, but companies like SpaceX and others are doing, it is an incredible moment for the next generation to be inspired, young Americans to work for you, to get involved in this mission, to get involved in the vision. You were just talking to Senator Sinema about your collaboration with universities. You know, I have raised the issue of the movie “The Martian” a couple of times.

One of my favorite movies in part because it is so inspiring for young people. Can you tell me a little bit more detail what you are doing, kind of, to really inspire the next generation of Americans, young Americans, who we can rely on for their science and technology expertise to really get them not only involved, but leading on the next exciting phases of NASA’s mission?

Mr. BRIDENSTINE. Yes, sir. So I will tell you the biggest thing that we can do as an agency to inspire that next generation that you talk about is we have to do stunning achievements. And as you identify, that is really what the American Moonshot was all about in the 1960s and that is what the Artemis program is all about today.

So when we think back to the 1960s, if you walk around people at NASA today and you ask them what made you get involved in the space, you know, business, the ones who are old enough will tell you that, you know, they can tell you exactly where they were when Neil Armstrong and Buzz Aldrin were walking on the moon. And then, of course, we did five moon missions after that. Every single one of them was impressive and inspiring. And that got that generation inspired to do space.

I will tell you, my generation, we were inspired by the space shuttles. I remember the first space shuttle launch. I was in kindergarten. And then we think about, you know, some of the setbacks that we saw with the shuttles, the *Challenger* and *Columbia*.

And my generation, we remember exactly where we were when those events happened. And I will also tell you—

Senator SULLIVAN. Sorry to interrupt, but can I just ask you, what is NASA doing—

Mr. BRIDENSTINE. Yes, sir.

Senator SULLIVAN.—right now to help get the word out? Are you going to campuses? Are you recruiting? Are you collaborating with Hollywood? I mean, what are you doing right now to actively get—because I think we are at this moment? It is very exciting.

And I think that the young people that I talk to see this as a great opportunity. But what are you doing exactly with some specifics to reach out, make them understand, and really get to a point where we can inspire a next generation of Americans to lead on these really important issues and of course, would have all kinds of knock off effects that are positive for our country, our society, like the Apollo missions have?

Mr. BRIDENSTINE. Absolutely. Yes, sir. So we invest through the Science Mission Directorate into what is called First Robotics, which gets young people involved in robotic capabilities. And of course, our agency is as filled with people who were involved in First Robotics when they were in high school or even before. We are engaging universities from the Space Grant and MURep kind of opportunities, EPSCoR, for example. These are all things that enable us to reach into those younger folks and share with them what we are doing, but also get them engaged, directly engaged in the missions that we do. And of course, contracting with universities throughout the United States to do some of these big missions is actually very big as well.

We started what is called the Lunar Surface Innovation Initiative, where we have partnered with now I think it is about 130 institutions across the United States using the Johns Hopkins Applied Physics Laboratory. They are kind of the integrator of the program where they are they are bringing all of these institutions across the United States to include a lot of universities together to create things like surface power on the Moon, and dust mitigation on the Moon, and how we are going to maneuver rove on the Moon, these kind of things, habitation on the Moon.

So, how we are going to use the resources of the moon to live and work for long periods of time. So we are engaging young people across the United States through those different programs. So and then, of course, you know, we even have programs that reach into elementary and junior high schools through the office of STEM Engagement at NASA. So we are doing what we can. You mentioned Hollywood. We are working to do private astronaut missions that might include some famous actors.

Senator SULLIVAN. Right. I don't usually mention Hollywood in this hearings, right but I do think that there is an opportunity here to really inspire. There have been some great movies that have that ability. So are you doing anything with them or other media types that can get the word out?

Mr. BRIDENSTINE. Absolutely. So we are creating a new program called Private Astronaut Missions. And we are working every day to make sure that people who are everyday people that want to go to space and do things, that we are making space available to

them. Now, those private astronaut missions are going to come with a price tag. We are not—we are not flying people to space for free. But certainly there is a lot of interest there from Hollywood and others. And so we are going to leverage all of that capability.

The CHAIRMAN. Thank you, Senator Sullivan.

Senator SULLIVAN. Great. Well, thank you, Mr. Chairman. I appreciate it. And if there is any other issues you want the Congress to work on you with that involves this issue of inspiring the next generation of Americans with the work that you are doing, let us know. I think it is a bipartisan issue here in the Senate that a lot of us want to get behind. So thank you. Keep up the good work.

Mr. BRIDENSTINE. Thank you, sir. And you can count on it. We will. We will call you.

The CHAIRMAN. Continued bipartisan enthusiasm about this subject matter. Senator Blumenthal.

**STATEMENT OF HON. RICHARD BLUMENTHAL,
U.S. SENATOR FROM CONNECTICUT**

Senator BLUMENTHAL. Thanks, Mr. Chairman. And you are absolutely right that there is bipartisan enthusiasm. And I am pleased to be a supporter and very passionate supporter of space exploration. My recollection, perhaps reflecting my age, about the first space exploration by man was the Sputnik, which was a sign of American potential failure, and then, of course a great recovery by this country, not without its mishaps and obstacles, but very, very inspiring in the end.

And space has always inspired man. My fear is that the moment that a lot of young potential scientists and explorers may be seeing right now is their dad being laid off from an aerospace company or contracting Coronavirus. On Earth here we have a pandemic. And I am concerned about the effects of that pandemic on our aerospace industry about potentially losing a whole class of early career scientists and losing companies that are struggling. I see them in my State of Connecticut and in particular in the area of aeronautics.

I note that the NASA investment in aeronautics is just 3 percent of the total budget. And I wonder whether you think that is sufficient, given the important impact of aeronautics, not only on scientific development, but also, quite honestly, on jobs and economic progress. Connecticut is known, as least we know ourselves as the aerospace alley. We are very proud of our role in aeronautics and aerospace. And I would like to know whether you think that that budget should be increased?

Mr. BRIDENSTINE. So I think the—a lot has changed in our country, as you have said, and we think about the Coronavirus pandemic, we think about the challenges with MAX 8. And that has had a devastating effect on aeronautics in general. I do believe that at this point in American history, now is not the time to rest on our laurels.

And I think there is room for additional support that we are going to need. This is a huge export for our country, which, as you identified, creates tons of jobs and it offsets the trade deficit that we have around the world in a significant way. We saw, when Boeing had its challenges with MAX 8, it impacted the GDP by about half a percent. I mean, that is a huge impact because of aero-

nautics. So I think the lesson taken from that is that if we were to make the right investments, earlier Senator Cantwell asked me about a truss braced wing, I think that is one investment that would be tremendously valuable.

But I would also say, and this might be of interest to Connecticut, we need small core engines, using advanced materials, higher pressure and temperature capabilities, because what we need out of our engines are higher bypass ratios for more fuel efficiency, fewer carbon emissions. Those are investments that we are investing in, in this budget, but I can also say that as we go forward, when we think about years in the future, it would be—there are very few investments I can think of that would have a bigger impact for the American economy than sustaining our leadership in aeronautics.

Senator BLUMENTHAL. So why not invest more? Only 3 percent of your budget.

Mr. BRIDENSTINE. So I think we have a good investment for this budget, for, you know, where we are right now. But I think as years go by, this is going to be an area that we are going to have to consider even more.

Senator BLUMENTHAL. Will you commit to a larger investment, given that we are in competition with other nations as well?

Mr. BRIDENSTINE. I can commit to that I will work toward that end.

Senator BLUMENTHAL. Let me ask about a different area, the Spacesuit program. As you know, on August 31st, the NASA Office of Inspector General notified the Congress of an impending audit examining NASA's management development of the next generation spacesuits for the lunar missions and future deep space exploration.

I have concerns about the issues with the current acquisition strategy for that next generation spacesuit and the potential effect it could have on companies in Connecticut. As you well know, Connecticut is very deeply involved in spacesuit development and production. Should we be concerned that there are technical and schedule issues with the next generation spacesuit, and what are you doing about them?

Mr. BRIDENSTINE. Yes, sir. So the key, I think, on the spacesuit issue is when we go to the Moon, as you know, an entirely different spacesuit because you have got dust, you have to be able to walk. The spacesuit that we use on the moon is very different than the spacesuit we use to do space walks on the International Space Station. So what NASA is doing rapidly right now is developing that capability.

And for the moon landing, for Artemis 3, we are going to be developing that internally, but we are doing it with an intent and forethought to make sure that what we want to see in the future is all of the production capabilities of these spacesuits be transferred to the commercial sector. And I think that follows along with our goal when we talk about the human landing system being developed commercially, we want spacesuits developed commercially as well. So we are moving toward that very rapidly. If there are specific things that we can work on together, I am happy to.

Senator BLUMENTHAL. Well, I would like to work with you, but may I suggest that engaging the industry perhaps more positively and proactively might be useful as well?

Mr. BRIDENSTINE. Yes, sir.

Senator BLUMENTHAL. Thank you.

The CHAIRMAN. Thank you, Senator Blumenthal. Senator Rosen.

**STATEMENT OF HON. JACKY ROSEN,
U.S. SENATOR FROM NEVADA**

Senator ROSEN. Thank you. Thank you, Mr. Chairman. Thank you, Administrator Bridenstine, for your enthusiasm, your knowledge. You mentioned Tang a while ago. It brought back a lot of childhood memories for me. And so my mom would put Tang on the breakfast table. That was really a big deal for us. And I am glad that you also mentioned MUREp because I want to talk about that too, women and minorities in research.

So, of course NASA, you have several programs to support states with space research and to help recruit, retain STEM students from underrepresented populations. As you know, NASA EPSCoR is a joint Federal State program designed to allow more states like Nevada to participate in space and aeronautics research. The Minority University Research Education Project, the one that you mentioned, MUREp, awards research grants to minority serving institutions with the goal of diversifying NASA's workforce as well as the larger STEM workforce.

I am proud to know that for the first time in our state's history a Nevadan was selected for a three year fellowship with the MUREp program, Alexandria Washington. She is an UNLV doctoral student. She is going to be working on a project to develop a robotic mobile platform that can traverse unique terrains like the kinds you are going to find perhaps on the Moon and explore places humans cannot yet reach.

However, despite the success of NASA's EPSCoR, MUREp, and other STEM education programs at NASA, the President's most recent budget request proposed terminating NASA's Office of STEM Engagement and proposed drastic cuts to funding EPSCoR, MUREp. So Administrator Bridenstine, you are so passionate about these programs. Can you describe your familiarity with the work that MUREp and EPSCoR is doing, the importance of increasing our diversity in scientific research?

Mr. BRIDENSTINE. Yes, ma'am. So I will say that the folks at NASA that are involved in the MUREp program are doing amazing work. And of course, it does, in fact, pay dividends. It is also true that what the budget request does is it focuses on the mission directorates and what they are trying to achieve as national goals.

And it really focuses on those activities that will help us achieve those national goals. Now, I would be clear, if the Senate funds, as the Senate has in past years, the Office of STEM Engagement, we are going to move forward and we are going to execute and those programs are going to serve NASA very well. But I also—

Senator ROSEN. Do you think that you will need the programs and the Office of STEM Engagement? Would you like to see us do that and see the President support that?

Mr. BRIDENSTINE. Well, I will tell you, it has been tremendously valuable. I would also tell you that I think there are other opportunities to fund those types of programs that would be more in alignment with NASA's missions. And that is really where the budget is focused. But I can—say that again?

Senator ROSEN. Would you share some of those programs with us? Your focus then, please?

Mr. BRIDENSTINE. Oh, sure. So, for example, when we think about contracting with universities, we initiated a program within the Aeronautics Mission Directorate, for example, that is a university leadership initiative where the Aeronautics Mission Directorate is partnering directly with minority universities to engage them in aeronautics activities, to include unmanned aerial systems and things like that that have a direct impact to NASA's mission.

We have other programs that we are doing through the Science Mission Directorate as it relates to robotics for going to the surface of the moon and other things. So I think we are all committed to achieving what you have highlighted is so important, which is creating that diversity for the workforce and creating that diversity for students, for opportunities. And I think I can very clearly say that we are committed to that agenda.

Senator ROSEN. I am concerned that you are trying to pull things into one enterprise solution, and so moving forward, I would really like to see, know how you plan to keep EPSCoR as a separate research enhancement program, not by diluting its mission by folding it into other programs. And, you know, speaking about our budget and if we scaled down, how are we going to then inspire those future generations, our space ambitions, going to Mars, going to other places if we don't invest in the next generation of NASA innovators?

Mr. BRIDENSTINE. Yes, ma'am. I think we are 100 percent committed to investing in that next generation and doing those really amazing, stunning achievements like the Artemis program where we are going to take not just the next man, but the first woman to the surface of the moon. And I can tell you, nobody is more excited for that than my 12 year old daughter.

And so I think these are the kind of things that we are focused on and we want to move out on. And certainly engaging all along the way MUREps and other institutions that encourage that next generation to get involved in the STEM fields.

Senator ROSEN. Thank you, I appreciate your service. I yield back.

The CHAIRMAN. Thank you, Senator Rosen. Senator Scott.

**STATEMENT OF HON. RICK SCOTT,
U.S. SENATOR FROM FLORIDA**

Senator SCOTT. Thank you, Chairman Wicker. Thank you for hosting this and I would just thank Chairman Wicker for his commitment to NASA and space exploration. You have had a lot of years up here and what I have watched over the years is you have had a significant commitment and I know it is important to your home state so thank you for that. As you know, NASA is pretty important to Florida, as it is in Mississippi and a few other states.

I became Governor back in 2010 and, you know, the space industry was in pretty bad shape then. We got the—I think we lost over 7,000 jobs in 2009, the Obama cuts, and when they stopped manned flight. But since then, the Federal Government has been a good partner in the state. When I was Governor, we put up a lot of money every year to get space exploration and bring it back. And now it is unbelievable what is going on there. And I just want to thank NASA for their commitment to using the private sector to do things.

I think it was a big deal this summer to see the SpaceX launch and so it was exciting to be there. I am sure your 12 year old daughter is excited. My 8 year old grandson is committed to be the first man on Mars. He is very comfortable between that and being a paratrooper and a policeman. He has picked—he told his mom he has picked jobs that are not dangerous. And he told me that it is not dangerous to go to space anymore.

Mr. BRIDENSTINE. OK, well that means we are doing a good job.

Senator SCOTT. But, you have created—I think what you have done is doing a good job of creating excitement for these young people. And I think that is going to pay off not just for the space industry, but just for STEM education in our country so thanks for doing that.

Mr. BRIDENSTINE. Thank you, sir.

Senator SCOTT. So what do you need that you don't have to continue the goal that I know that you have and the President have, and the Chairman, Chairman Wicker has to continue to explore space and to do it in a responsible manner?

Mr. BRIDENSTINE. Yes, sir. I think probably the biggest thing, and especially for the State of Florida—and I want to say that the State of Florida had benefited greatly when you were a Governor with the establishment of Space Florida and all those commercial activities and your leadership on that.

And now, you know, the Kennedy Space Center in Cape Canaveral being this multiuser spaceport. So the vision there and the execution has been very helpful to us as an agency and we are grateful for that. A couple of things that I think are important to note. We all know that the International Space Station is going to come to an end of its life at some point. It cannot last forever. And of course, it has been—you know, in November, we are celebrating 20 years of a continually occupied space station. That is a long time and amazing.

But we need to start making the investments for what comes next. And that what comes next is the commercialization of low Earth orbit. As you have seen, we have done Commercial Resupply. We have now done Commercial Crew, launching American astronauts from the space coast there in Florida. The next big thing is commercial space stations. All of those resupply missions and those commercial crew missions need a place to go. And if the International Space Station comes to the end of its life and we don't have commercial space stations, there is going to be a lot of rockets that aren't going to get launched. And I think it is important that we fund our efforts as an agency for those commercial space stations.

We have put that in the budget request in years past and it hasn't gotten funded. That is critically important for the country. China is building their own what they call the Chinese International Space Station. They are working very hard to attract our international partners, which we have helped build their capacity and now they are going to potentially take that to China. We are working to prevent that from happening.

But at the same time, it is important for us to think about the architecture that we need. We need Commercial Resupply, Commercial Crew, Commercial Habitats. NASA needs to be a customer there. We will be a tenant customer. But we need to change the paradigm like we have done with launch vehicles. We need to change the paradigm for habitation in space and then apply what we have learned within those programs to commercial access to the moon.

We are happy and excited that, you know, in November of next year, we are going to launch the most powerful rocket that has ever been built. It is currently being tested at Stennis. We are going to get that rocket—.

Senator SCOTT. Which State does that? Yes, I wonder which State.

Mr. BRIDENSTINE. So without Mississippi, we can't get that rocket to Florida. And so it is an all of the above strategy and certainly we are excited about launching that next year. So I would—you asked what we need and I am making the best case I can that we need to start thinking about what happens next in low Earth orbit.

Senator SCOTT. I know the Chairman will be supportive of trying to do space exploration. Let me just finish by just asking you, or thanking you. You have been a real partner in the Visitor's Center, and I think it does an unbelievable job of exciting families about what goes on in space. And so thanks for being a partner. I know they work really hard to try to do a great job and excite kids to want to explore space. So thank you for what you are doing.

Mr. BRIDENSTINE. It is an amazing place.

Senator SCOTT. Thanks.

The CHAIRMAN. Thank you, Senator Scott. And thank you for that shout out for the Stennis Space Center in Mississippi. Administrator Bridenstine, you had a little bit of a rocky confirmation process before this committee——

Mr. BRIDENSTINE. I don't remember.

The CHAIRMAN. Well, I do. And let me just say that you have won over a number of skeptics and I think the bipartisan support for the job you are doing has been indicated very profoundly today and I appreciate the job you are doing. The drink Tang has been mentioned. Let me just say that every time you come on the screen today, you have been an advertisement for Mountain Dew, and I think that I think PepsiCo needs to make a great contribution to NASA based on all of the publicity that you have given them today.

That said, the hearing record will remain open for two weeks. During this time, Senators are asked to submit any questions for the record. Upon receipt, our distinguished witness is requested to submit his written answers to the Committee as soon as possible.

Mr. BRIDENSTINE. Yes, sir.

The CHAIRMAN. So with that, we conclude the hearing and express our appreciation to Administrator Bridenstine.
Mr. BRIDENSTINE. Thank you, Chairman.
[Whereupon, at 11:39 a.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARSHA BLACKBURN TO
HON. JIM BRIDENSTINE

Question 1. One of the hallmarks of NASA is its ability to encourage new generations of scientists and engineers by example and through outreach. Looking at your FY2021 budget request, however, I was greatly concerned seeing that you've zeroed out funding for the Office of STEM Engagement in favor of exploration. While I agree that exploration is the core mission of NASA, I think a lack of STEM engagement could have severe long-term consequences. How do you intend to engage the next generation of researchers and explorers with zero funding in this office?

Answer. The functional Office of STEM Engagement at NASA Headquarters will continue to oversee Agency-wide strategic direction and coordination of NASA's STEM engagement efforts. A common vision, mission, and strategic goals would continue to drive NASA's future endeavors in STEM engagement. Through Mission Directorate activities, NASA would continue to create unique opportunities for a diverse set of students to contribute to NASA's work; build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content and facilities; and attract diverse groups of students to STEM through learning opportunities that spark interest and provide connections to NASA's mission and work. NASA's mission and endeavors in exploration and discovery would continue to inspire the next generation to pursue STEM studies.

Question 2. Like many other Americans, I'm looking forward to seeing the James Webb Telescope's first light in orbit. While its potential is immense, this project has been subject to cost overruns and schedule delays. The latest expected launch date of March 2021 is likely going to be delayed due to the COVID-19 pandemic. This is understandable given the circumstances; however, I'm concerned this delay may result in even more of NASA's funds being siphoned away from other projects to support the telescope. Do you have an update on the expected launch date, and how do you intend to mitigate the costs associated with any delays?

Answer. Earlier this year, NASA completed a planned schedule risk assessment for the James Webb Space Telescope (Webb) addressing remaining integration and test activities before launch. As a result, the new Launch Readiness Date for Webb is October 31, 2021, with a development cost estimate of \$8.8 billion. NASA conducted a cost analysis that concluded the development budget estimate remains unchanged, with no increases to its lifecycle cost and adequate to fund Webb through launch.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO
HON. JIM BRIDENSTINE

Question 1. What is the status of the Transonic Truss Brace Wing aircraft and what are the next steps to move from planning to development and flight testing such an X-plane?

Answer. The Transonic Truss Braced Wing (TTBW) concept has been studied by NASA and Boeing since 2008. This concept has been the subject of multiple wind tunnel tests, from 2011 through 2019, to study its performance and attributes under various simulated flight conditions. With each of these tests, the NASA team of researchers has learned more about the configuration's behavior and potential to significantly reduce fuel burn and carbon emissions. Specifically, in the 2019 tests, NASA confirmed the potential of the TTBW's aerodynamic efficiency at high-speed cruise conditions and the ability to integrate a high-lift system for low-speed take-off and landing conditions. At present, NASA is preparing for further low-speed tests of a TTBW model in the 14x22-foot wind tunnel at NASA Langley Research Center exploring off-nominal conditions such as ice impacts, and high-speed tests in the 11x11-foot wind tunnel at NASA Ames Research Center exploring unique off-nominal, aerodynamically-induced vibration characteristics. These tests will provide

additional insights into how the TTBW configuration performs throughout a range of projected flight conditions.

Additional insights from currently planned wind tunnel testing could inform future decisions on potential flight testing of a TTBW configuration. In FY 2021, NASA plans to identify options and better understand the pros and cons of various flight test approaches. NASA recently released a Request for Information (RFI), link below, the responses to which will help inform options for further advancing this technology.

https://beta.sam.gov/opp/9322f65e4e0d457fa0824c6dfa9692fd/view?keywords=80afrc21ss003&sort=-relevance&index=&is_active=true&pa

Once responses to the RFI are received, NASA will hold additional discussions with U.S. industry and with NASA subject matter experts to gain deeper insight into potential flight test approaches and associated timelines, projected costs, and necessary engagements and partnerships with industry.

Question 2. What level of insight will NASA have on commercial spaceflight systems procured as a service?

Answer. NASA employs varying degrees of insight that are uniquely tailored for each commercial spaceflight system effort. The level and type of insight varies based on factors such as the nature of the services NASA is acquiring; the risk level of these services; the development maturity and flight history of the spaceflight system providing the service in question; NASA's familiarity with, and prior involvement on, the capability; and whether the service procured relies on mature capabilities developed under prior NASA-funded efforts. For instance, NASA's contracts for the development and provision of crew transportation capabilities such as Commercial Crew and Human Landing System mandate substantial NASA insight into the contractors' safety and mission-critical development activities throughout contract performance. In general, NASA will have sufficient insight into any commercial spaceflight services contract to enable the Agency to verify that its requirements have been satisfactorily met.

Question 3. In the event of a spaceflight mishap, what role do you think NASA should play in the investigation of a commercially licensed spaceflight if NASA also flies on that spacecraft or rocket?

Answer. Since the enactment of U.S. Code, Title 51, Chapter 707 in 2005, which requires the establishment of a Presidential Commission in response to many mishaps involving commercial vehicles, NASA's human spaceflight mission has evolved significantly. The Space Shuttles have been retired, and in the post-Shuttle era, the Agency's human spaceflight activities are becoming more varied. In addition to the ongoing full-time occupancy of the International Space Station (ISS), there are operational Commercial Crew flights to and from the ISS, and there will be human spaceflight missions beyond low-Earth orbit (LEO) with Orion and the Space Launch System (SLS), including missions to the lunar Gateway and to the lunar surface using contractor-provided Human Landing Systems (HLS). As a result, NASA will require an investigative process flexible enough to deal with incidents that may occur in different flight regimes, while responsive enough to avoid unnecessarily lengthy delays in safely resuming flights. This process must be comprehensive, transparent, responsive, tailored, and timely to maintain safe, continued permanent occupation of the ISS, and maintain the Nation's commitments to its international partners.

NASA's Commercial Crew Program (CCP) is using commercial space vehicles to transport crew to the ISS and these launches are licensed by the Federal Aviation Administration (FAA). Currently, the National Transportation Safety Board has the responsibility for investigating commercial human space mishaps, such as the Virgin Galactic accident in 2014.

Question 4. What are the testing requirements for the lunar landers and will NASA require in-space testing?

Answer. The HLS procurement is designed to allow the contractors to propose commercial solutions and use commercial strategies and standards, as long as those approaches are ultimately approved by NASA and also meet all of NASA's contractual performance requirements. This philosophy, when applied to testing requirements, resulted in a situation in which NASA did not mandate a high number of specific tests, but rather, mandated technical and safety standards that required the contractor to develop and propose its own suggested tests. For example, an HLS technical standard might require the contractor to perform a "demonstration of loads capability." But it is then up to the contractor to propose the specific test or demonstration that they will use, and when, to meet that requirement. Through each phase of the HLS competition, contractors are required to propose a wide variety of tests, including ground testing, in-space testing, and associated technical

analyses for their respective capabilities in order to meet these requirements. A notable exception to this overall approach to testing is that NASA is requiring the HLS contractors to successfully execute uncrewed lunar landing tests of their HLS capabilities prior to performing crewed demonstrations.

Question 5. In the aviation certification bill I am working on with Chairman Wicker, we called for the establishment of a “Technical Certification Board” that could advise the FAA during the certification of aircraft involving new technology or novel design. Does NASA have the expertise to advise or inform the FAA on certification or development of civil aircraft?

Answer. NASA does not participate directly in the FAA certification process because the Agency’s expertise is aligned with a different mission as a technical research organization. NASA conducts cutting-edge research to generate and develop innovative concepts, technologies, capabilities and knowledge to enable revolutionary advances for a wide range of air vehicles. NASA Aeronautics works closely with counterparts in the FAA to coordinate and share information about our research activities, and through these exchanges can gain an understanding where there may be knowledge gaps associated with new and emerging areas. NASA can help provide sound, scientifically-based data to the FAA about our research and the current state of the art in associated technologies. NASA research also helps inform technical standards that can be integral to the certification process.

Question 6. COVID–19 has negatively impacted many sectors, including the aerospace industry. In the CARES Act, Congress gave agencies the ability to extend contract flexibilities in section 3610, which were recently extended until mid-December. What is NASA doing to mitigate these impacts and to what extent are those efforts enabled by section 3610?

Answer. NASA Office of Procurement issued Procurement Information Circular (PIC) 20–02A entitled, “Novel Coronavirus Disease 2019 (COVID–19) Contractor Guidance” on May 4, 2020, updated June 4, 2020. The purpose was to provide a path forward for NASA Contracting Officers and NASA Contractors regarding work, cost incurrence, and reporting related to ongoing work or interruptions associated with COVID–19 with the goal of preserving the space industrial base and maintaining mission operational readiness to assume full performance of all contract requirements when the emergency passes. NASA has enabled certain flexibilities such as maximizing telework use and identification of alternate work that can be performed remotely.

As identified in the Agency’s Memo to NASA Contractors signed on March 24, 2020, Contractors were required to “maintain readiness to assume full performance of all contract requirements when the emergency has passed.” To facilitate a mobile ready state, NASA has authorized contractors to use existing clauses in their contracts. These include NFS 1852.242–72, Denied Access, when a NASA facility is closed and there is no work that the contractor’s employees can accomplish from a remote location; FAR 52.242–15, Stop Work Order (Offsite) when a contractor informs us that they cannot safely perform work at their facilities, either due to state guidelines or their own internal assessment; and applicable clauses such as 52.212(4) Terms and Conditions for Commercial Items.

NASA also has enabled contractors to submit requests for reimbursement of employee leave costs when NASA or contractor facilities are closed or restricted and the employee’s job cannot be performed remotely, as authorized by Section 3610 (Federal Contractor Authority) of the “Coronavirus Aid, Relief, and Economic Security Act” (P.L. 116–136) (“the CARES Act”). Accordingly, NASA has developed an Advance Agreement template to be used by Contracting Officers to establish terms between NASA and the Contractor in a proactive manner that will regulate subsequent requests for equitable adjustments and provide for provisional billing during facility closures related to COVID–19.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. AMY KLOBUCHAR TO
HON. JIM BRIDENSTINE

Diversity in STEM. Ensuring diversity in STEM fields is a top priority for me. I introduced bipartisan legislation that was signed into law in March to encourage veterans and military spouses to pursue careers in STEM fields, and I also led bipartisan legislation to encourage women and minorities to pursue careers in aerospace and STEM that was signed into law in 2017.

Question 1. Can you speak to the importance of ensuring that we have a diverse workforce in the STEM field?

Answer. Building a strong Science, Technology, Engineering, and Mathematics (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.

Question 2. In Fiscal Year 2021, NASA did not submit any funding requests for STEM education. What actions is NASA taking to continue its outreach to students and veterans to encourage them to pursue education in STEM fields?

Answer. The functional Office of STEM Engagement at NASA Headquarters will continue to oversee Agency-wide strategic direction and coordination of NASA's STEM engagement efforts. A common vision, mission, and strategic goals would continue to drive NASA's future endeavors in STEM engagement. Through Mission Directorate activities, NASA would continue to create unique opportunities for a diverse set of students to contribute to NASA's work; build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content and facilities; and attract diverse groups of students to STEM through learning opportunities that spark interest and provide connections to NASA's mission and work. NASA's mission and endeavors in exploration and discovery would continue to inspire the next generation to pursue STEM studies.

NASA and COVID-19 Funding. The CARES Act appropriated \$60 million to NASA so the agency could better protect itself from any negative effects related to the coronavirus pandemic. Earlier this year, NASA instituted a mandatory telework policy for all employees with limited exceptions for essential workers.

Question 1. Beyond implementing a mandatory telework policy, what measures is NASA taking to prioritize the health and safety of its workforce?

Answer. The health and safety of NASA's workforce has always been and remains NASA's top priority during this challenging time period.

NASA is currently using a NASA-developed Return to On-Site Work Framework¹ (RTOW) to safely increase the amount of work being done on site at our Centers and facilities. Increased levels of RTOW will be gradual as local conditions at each NASA Center/facility become safer. NASA also has strict safety protocols in place for employees who are returning to on-site work, including requiring all employees (civil servant and contractor) and anyone else who enters a NASA facility to wear face masks when they cannot ensure appropriate social distancing. NASA continues to investigate other technologies that may provide protections for our workforce. Should an employee who has been on site test positive for COVID-19, NASA has a contact tracing protocol to identify and notify others who may have been exposed to an infected person. NASA then requires infected and exposed persons to self-quarantine, and we have aggressive cleaning protocols for impacted areas. NASA also continues to actively communicate with other Federal agencies about how we are responding to the COVID crisis and to share best practices with them, while also learning from the successes of others.

During these challenging times, NASA continues to keep our workforce informed about RTOW plans via e-mails from senior leaders, virtual townhall events, and Agency-wide and Center-specific websites. Additionally, NASA senior leadership continues to put our employees first by maximizing flexibilities for employees to perform their NASA work while also enabling them to care for themselves and their families. Leave and telework flexibilities consistent with Office of Personnel Management (OPM) guidance are available to employees, including limited paid leave for care of young children. We also have encouraged our supervisors to provide the greatest amount of flexibility in what hours employees work., *e.g.*, allowing them to change start/stop times or to break up their eight-hour workdays into sections to better accommodate their family needs at home. NASA leaders also are aware that some employees are working beyond core hours given the demand for their expertise, so we are also cognizant and trying to minimize the stress these employees are facing. As such, NASA is also encouraging employees to "unplug" and take breaks during the day and we've encouraged supervisors and employees to have "quiet Fridays" twice a month, which means employees should do their best to avoid scheduling meetings and other events on these Fridays, allowing them to focus solely on other duties without the constant interruption of virtual meetings and phone calls—

¹The following website includes specifics about our RTOW plans; including a copy of our RTOW Framework; a list of Frequently Asked Questions and Answers; and a list of the each Center's operational status: <https://nasapeople.nasa.gov/coronavirus/coronavirus.htm>.

something employees say has been a challenge while working remotely. NASA leaders also have encouraged employees to use their annual leave to recharge and take care of other priorities in their lives.

Of even greater importance, NASA remains concerned about the emotional and mental wellbeing of our employees—many of whom haven't been on site at work since March 2020, and who may be suffering from the negative effects of being isolated from family, friends and colleagues, or suffering from heightened stress at home during this pandemic period. Therefore, NASA has encouraged supervisors to "check in" on their employees more frequently, as well as finding creative ways that groups can socialize virtually without talking about work. NASA continues its strong support of mental health and wellness through many ongoing outreach programs, including our Employee Assistance Program. Additionally, NASA's Office of the Chief Health and Medical Officer has prepared a new mental health/suicide prevention toolkit to ensure NASA leaders and the workforce are educated about the risk factors associated with suicide, while also giving them actionable ways to help someone they may identify as high-risk or potentially suicidal—whether that be a coworker or a friend or family member.

Question 2. Does your agency anticipate that current limitations on in-person work will affect NASA's ability to meet its long-term goals?

Answer. NASA's mission and our long-term goals have not changed as a result of the pandemic. Instead, our amazing workforce has continued to get the job done, even while working remotely.

In mid-March, Agency senior leaders began making the difficult decisions to move nearly the entire workforce, Center-by Center based on local conditions, into a telework status. Only a limited number of employees performing mission-critical work requiring on-site access for the protection and safe operation of critical Agency infrastructure and a few select missions (*e.g.*, DM2 launch and Mars Perseverance preparations) were initially authorized to be on site, following clearly defined health and safety protocols. Thus, NASA has never been "closed." On the contrary, our employees continue to perform NASA's important missions under very difficult personal and professional circumstances, leveraging technology and communication tools to continue a majority of NASA's work. More than 90 percent of the NASA workforce was in a telework status by the end of March 2020. As of mid-October, about 75 percent of employees and contractors are continuing to work remotely, with the amount varying by mission requirement and location. We have also continued to hire and onboard new employees and contractors, and to support summer interns with virtual learning opportunities. We have even worked with our commercial and international partners to launch several spacecraft during this timeframe. We have seen individuals and teams find new ways to keep the mission moving forward, to support each other, to balance work and family, and even dedicate their expertise and personal time to partner with local companies to help develop technologies to help treat COVID patients and to better protect frontline responders. NASA employees have capitalized on new ways to virtually connect within their teams and with external partners via online tools.

At the same time, however, it is true that the pandemic has caused some negative mission impacts since work was delayed when employees couldn't be on site, or because there were other challenges that arose, and resources had to be diverted to them in an expedient manner. Because there remains significant uncertainty about the duration and severity of the pandemic, the progress of restart activities at NASA and contractor/partner facilities, and the long-term implication to domestic and international partner capabilities, a full assessment of the impact of COVID-19 on NASA will not be available until well after the crisis has passed.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TOM UDALL TO
HON. JIM BRIDENSTINE

Question 1. What are the next steps for the Suborbital Crew program after NASA's recent Request For Information (RFI)?

Answer. There are two primary milestones over the coming year for the Suborbital Crew program: 1) development of a system qualification process for the commercial suborbital vehicles, and 2) preparation of an acquisition for system qualification and potentially services for commercial suborbital transportation. The timeline for these milestones is not firm at this time, but NASA is targeting the Spring of 2021 for completion of the system qualification process and the acquisition to follow some months after that.

Question 2. What is the time-frame for NASA to begin purchasing rides on commercial suborbital vehicles, such as those provided by commercial space flight companies based in New Mexico, like Virgin Galactic?

Answer. The Flight Opportunities program has supported 196 flights from its formation in 2011 through FY 2020. Flight tests have been performed on a variety of commercial suborbital vehicles, including Virgin Galactic and UP Aerospace, which operate out of Spaceport America. Flight Opportunities will continue to make use of commercial suborbital flights for testing of technology payloads in FY 2021 and beyond, including supporting opportunities for researcher-tended experiments on qualified vehicles. Regarding purchasing rides on commercial suborbital vehicles for NASA personnel, please see the response to Question #1.

Question 3. New Mexico universities are developing strong space-related programs and have benefited greatly from NASA grant funding, such as the Flight Opportunities Program, Minority University Research and Education Project, and Next Generation Additive Manufacturing for Space Applications. As NASA plans for the future, will expanding these programs be a priority?

Answer. Flight Opportunities recently selected a record 31 technologies in FY 2020 under the annual Tech Flights solicitation to universities and industry. The FY 2020 solicitation also provided additional funding to enable proposers to incorporate educational activities into their research. The majority of the requests received were for collegiate-level educational activities. Based on Congressional direction, the Flight Opportunities program is also poised to release a nationwide educational initiative aimed at K–12 students that will start in FY 2021. Flight Opportunities also teamed with the NASA Office of STEM Engagement to help fund a Hawaii Space Grant project to support suborbital flight tests for an undergraduate team of ~20 engineering students developing CubeSat technologies. The Next Generation Additive Manufacturing for Space Applications is managed by the NASA Established Program to Stimulate Competitive Research (EPSCoR) project. EPSCoR seeds projects that help states develop the capacity to compete successfully for aerospace-related research funding and is not intended to provide long-term support.

The President’s Budget proposes to terminate funding for grant programs currently managed by the Office of STEM Engagement. The functional Office of STEM Engagement at NASA Headquarters will continue to oversee Agency-wide strategic direction and coordination of NASA’s STEM engagement efforts. A common vision, mission, and strategic goals would continue to drive NASA’s future endeavors in STEM engagement, including working with Minority Serving Institutions.

Question 4. With support from Congress, how would expanding programs such as the Flight Opportunities Program, Minority University Research and Education Project, and Next Generation Additive Manufacturing for Space Applications, shape the future of the NASA workforce?

Answer. The so-called “democratization of space” through the lower-cost and more-frequent access afforded by CubeSats and commercial suborbital flight allows students to experience one or more space missions before ever coming to work for NASA. These platforms also provide opportunities for internal workforce development and retention. Flight Opportunities intends to continue supporting suborbital flights for university-led technology payloads; provide funding for educational research opportunities on suborbital flights; contribute to the NASA CubeSat Launch Initiative for K–12 schools, universities and non-profits; and provide suborbital flights to technologies under NASA’s Early Career Initiative. With the support of Congress, Flight Opportunities continues to bolster commercial flight capabilities that can further this democratization of space and move technologies from laboratory to orbit in months instead of years.

The President’s Budget proposes to terminate funding for grant programs currently managed by the Office of STEM Engagement. The functional Office of STEM Engagement at NASA Headquarters will continue to oversee Agency-wide strategic direction and coordination of NASA’s STEM engagement efforts. A common vision, mission, and strategic goals would continue to drive NASA’s future endeavors in STEM engagement, including working with Minority Serving Institutions.

It is important to understand that NASA’s Science, Technology, Engineering, and Mathematics (STEM) engagement and outreach efforts have always occurred beyond the walls of the Office of STEM Engagement, *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. These are just a few of the STEM activities that NASA employees across the Agency proactively engage on every day. NASA’s mission successes will continue to inspire the next generation to pursue science, technology, engineering, and math-

ematics 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.

In addition to these programs, NASA uses many Governmentwide civil service hiring authorities and programs to shape the workforce. The Pathways program, focused on internships, recent graduates, and Presidential Management Fellows, is another student program used extensively at NASA.

Question 5. NASA recently outlined plans for realization of a future market for lunar resources. How can private sector companies in the United States participate in these markets?

Answer. Learning to “live off the land” is vital to the long-term sustainability of human exploration and development of the Moon, Mars, and other destinations, and NASA is taking steps to catalyze the private sector's development of in-situ resource utilization (ISRU) capabilities. Toward this end, NASA has funded and will continue to fund the strategic development and demonstration of key technologies related to ISRU from a number of commercial sources, including small businesses. Further, on September 10, 2020, NASA released a solicitation for the purchase of lunar regolith obtained by private sector companies on the lunar surface. After collection by these companies, transfer of ownership of lunar regolith to NASA will occur “in place” on the lunar surface, after which, the collected material becomes the sole property of NASA. On December 3, 2020, NASA announced the selection of four companies to collect space resources and transfer ownership to the Agency: Lunar Outpost of Golden, Colorado; Masten Space Systems of Mojave, California; ispace Europe of Luxembourg; and ispace Japan of Tokyo.

Question 6. To realize future market for lunar resources, does NASA have plans to partner with other entities like national laboratories such as Sandia National Lab or Los Alamos National Lab?

Answer. NASA is currently examining multiple approaches to partner with both domestic and international entities in the public and private sectors in order to realize future markets for lunar resources. Partnerships with national laboratories, such as Sandia National Lab or Los Alamos National Lab, may offer unique opportunities to address Agency requirements and/or policy objectives.

Question 7. How is NASA planning to use suborbital flights and the Flight Opportunities program for rapid research and development and prototyping that can support the Artemis program?

Answer. Four companies selected as Commercial Lunar Payload Services (CLPS) providers and two of the teams selected to develop Human Landing Systems (HLS) for the Artemis program include companies that have served as flight providers or tested technologies through Flight Opportunities. In addition, at least four of the payloads selected to fly to the Moon aboard the commercial landers to date were matured in part through Flight-Opportunities supported suborbital flight testing. The Space Technology Mission Directorate (STMD) also recently selected Masten Space Systems for a Tipping Point public-private partnership contract to construct a next-generation suborbital test bed for lunar landing technologies.

Question 8. NASA plays an important role in monitoring and reporting on climate change and the impact climate change has on the Earth. As NASA plans for the future, what programs and initiatives are planned to continue this vital work?

Answer. NASA's role is to advance Earth system science and applications, including climate science. To do that, NASA measures the Earth's physical and biological characteristics from space and uses the measurements to understand Earth's systems and processes—including interactions among land, ocean, atmosphere, and cryosphere/ice—as well as the role of human communities in these processes. NASA uses our understanding of natural and human processes and their interactions to provide objective information on changes happening now as well as estimates of how our environment might evolve in the future. NASA will continue to support world-leading climate change research, high-performance computing and Earth system modeling, and is developing the next generation of space-based missions that will collect observations needed to advance our understanding of the interconnected Earth system and changes to the Earth system over time.

Through Research Opportunities in Space and Earth Sciences (ROSES) solicitations, NASA annually funds competed, peer-reviewed research in climate variability and change at U.S. research institutions to better understand the overall state of Earth's climate and the physical processes that affect it. This research includes the continued development of climate data sets and computer models that leverage observations from relevant NASA and non-NASA platforms, including satellites, air-

craft, and ships, enabling scientists to better predict changes in Earth's climate from sub-seasonal to multi-decadal timescales. NASA's Earth Science Division (ESD) plans to provide continued, long-term support to its Modeling, Analysis, and Prediction (MAP) Program, which includes directed funding to the Goddard Institute for Space Studies (GISS) Model E and the Global Modeling and Assimilation Office's (GMAO) GEOS 5 Earth system models, as well as annual competed grants. Using observations from satellites, instruments on the International Space Station, airplanes, balloons, ships, and on land, ESD researchers collect data about the science of our planet's atmospheric motion and composition; land cover, land use, and vegetation; ocean currents, temperatures, and upper-ocean life; and ice on land and sea. These datasets, which cover even the most remote areas of Earth, are freely and openly available to anyone.

NASA/ESD also develops, launches, and operates a fleet of Earth observing satellites and instruments, acquiring measurements of many different environmental quantities from the vantage point of space. The vantage point of space allows measurements of the complex Earth system that can fully illuminate the connections between short and long time scales; fine and global spatial scales; and chemical, physical, and biological processes. From space, we can make measurements that have high spatial resolution and global coverage with uniform accuracy; and frequently sample measurements at all locations for long periods of time, including the wide range of oceanic, atmospheric, and terrestrial observations needed to understand the connections between Earth system processes as well as the workings of the individual processes themselves.

The NASA/ESD orbiting fleet presently includes 22 Earth observing satellite missions and major instruments, with another 12 missions and major instruments in development for launch between November 2020 and the end of Fiscal Year 2023. The recently launched Sentinel-6 Michael Freilich satellite will contribute to the Earth Science portfolio. Specifically, this satellite will collect the most accurate global data yet on sea level and how it changes over time, expanding upon nearly 30 years of continued sea surface height observations. NASA is in the planning stages for new missions that will begin development in 2023 and beyond, consistent with the major Decadal Survey recommendations for new missions and instruments to address pressing unanswered questions about our Earth system.

NASA/ESD is also engaging in new, innovative partnership approaches with the private sector, including both non-profit and for-profit organizations. ESD is using hosting opportunities to place selected NASA Earth observing research instruments on commercial geostationary communications satellites and private-sector low-Earth orbiting spacecraft. NASA also procures commercial data through the Commercial Smallsat Data Acquisition program. These efforts augment data from NASA systems with data products that can contribute to the advancement of Earth systems science and climate change research.

Question 9. How does NASA plan to utilize the information to develop climate change solutions?

Answer. NASA does not make environmental policy, nor does NASA have any regulatory authority in the area of Earth observation. NASA's role is to provide unique, comprehensive observations of our environment, to conduct research leading to greater understanding of the Earth, and to make the observations and the understanding available to government policy makers and decision-makers of all sorts, within and external to the Federal Government.

Through our longstanding free and open data policy, NASA provides its datasets, models, and research results to anyone who wants to use them without cost. For example, data from NASA/ESD research satellites are provided in near-realtime to operational agencies, such as the National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense (DoD), and used routinely by those agencies to improve the accuracy of their environmental predictions. In addition, we support a number of programs through the ESD's Applied Sciences program that work to make NASA's observations, including climate-related observations, more accessible and useable to leaders and decisionmakers across sectors in the U.S. and around the globe so that NASA's wealth of Earth data and scientific insight can be better leveraged for societal benefit.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. GARY PETERS TO
HON. JIM BRIDENSTINE

Question 1. NASA recently released its Economic Impact Report—which has a breakdown of NASA's economic impact and associated jobs in each state. NASA obviously has a long history in certain states—which explains a large disparity in eco-

conomic impact among states. However, the report is somewhat troubling particularly when you look at America's most industrial states like Michigan and Wisconsin and Illinois—in which NASA has a disproportionately small economic impact. That is one reason why I authored an amendment in the NASA Reauthorization Act of 2019 to direct NASA to survey supply chain capabilities—including for the defense sector, which may have overlapping relevance to NASA—and to establish a Supply Chain Center of Excellence in a state that NASA does not already have a significant presence. Given your recent M–O–U with General Raymond and the Space Force—do you think this can be another area where you can seek assistance from the Department of Defense to bolster your supply chains and economic impact in the industrial Midwest?

Answer. Through its expansive portfolio of partnerships with the Department of Defense (DoD), NASA has broad and robust access to defense sector supply chains. Like its other partner U.S. Government departments and agencies, NASA has a vested interest in the vitality of the U.S. domestic industrial base, and in the aerospace/defense industrial base in particular. To gain insight and to address concerns over the health of the aerospace industrial sector, NASA, the Federal Aviation Administration, the National Reconnaissance Office, the Missile Defense Agency, the Department of Energy, the Department of Commerce, and DoD formed and are members of the Space Industrial Base Working Group that examines how these departments and agencies could share space technology, collaborate on space-related acquisitions, and how the Government purchases technology from the private sector. Further, DoD represents NASA for its priority procurements utilizing the Defense Priorities and Allocations System.

Question 2. This past year, Michigan Technological University researchers had the privilege of meeting you and discussing their contributions to NASA's efforts to develop a robust in-situ resource utilization plan for the Moon. When can we expect more comprehensive details of NASA's plans for in-situ utilization on the Moon and what if any hurdles do you foresee for NASA releasing a roadmap in this area?

Answer. STMD plans to publish its Strategic Investment Technology Plans, including in-situ resource utilization (ISRU), for public review in mid-CY 2021. NASA intends to utilize the Lunar Surface Innovation Consortium (LSIC), facilitated by Johns Hopkins Applied Physics Laboratory (APL), as well as other public forums, to engage industry, academia, and the public in the development and vetting of these technology plans. As a member of the LSIC, and by participating in the ISRU focus group meetings, Michigan Technological University has the opportunity to provide input into NASA's drafting of the technology plans.

In parallel, the Space Technology Mission Directorate (STMD) continues to offer a multitude of ISRU opportunities for collaborations, challenges, and public private partnerships with universities and industry. Some examples include the recent Tipping Point and Announcement of Collaborative Opportunity awards, the Lunar Surface Technology Research (LuSTR) opportunities, Small Business Innovation Research (SBIR) awards, and the Breakthrough Innovative Game-Changing (BIG) Idea university challenges.

Question 3. You noted the increasingly common requirement to maneuver the International Space Station to avoid catastrophic impacts from orbital debris. Nearly a decade ago, DARPA completed their "Catcher's Mitt Study"—detailing the threat from orbital debris and concluding that debris removal will be required, including in Low-Earth Orbit. That study was well before the FCC approved licenses for satellite constellations that will amount to more-than-doubling the number of satellites in orbit. China, similarly is planning major satellite constellations in LEO. What is NASA doing on the debris mitigation front?

Answer. Controlling the growth of the orbital debris population is a high priority for NASA, the United States, and the major spacefaring nations of the world to preserve near-Earth space for future generations. Mitigation measures can take the form of curtailing or preventing the creation of new debris, designing satellites to withstand impacts by small debris, and implementing operational procedures such as using orbital regimes with less debris, adopting specific spacecraft attitudes, and even maneuvering to avoid collisions with debris.

A U.S. interagency working group led by NASA and DoD developed a work plan to study the debris environment and to work with U.S. Government agencies and other spacefaring nations and international organizations to design and adopt guidelines to minimize orbital debris. In 1997, the working group created a set of U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP). Based on a NASA standard of procedures for limiting debris, the Standard Practices are intended for Government-operated or -procured space systems, including satellites as

well as launch vehicles. The Standard Practices were approved by all U.S. Government agencies by February 2001.

Consistent with direction in Space Policy Directive 3, in December 2019, NASA published an update to the ODMSP which includes improvements to the original objectives as well as clarification and additional standard practices for certain classes of space operations. For example, the update incorporates new sections to clarify and address operating practices for large constellations, rendezvous and proximity operations, small satellites, satellite servicing, and other classes of space operations. The 2019 ODMSP, by establishing guidelines for U.S. Government (USG) activities, provides a reference to promote efficient and effective space safety practices for other domestic and international operators. The USG intends to update and refine the ODMSP as necessary in the future to address advances in both technology and policy.

Question 4. As a member of the Armed Service Committee, I am concerned about the threat that orbital debris poses to our military assets in space. Orbital debris mitigation was included in the M–O–U that you recently signed with General Raymond of the Space Force. What do you envision this will entail and do you think an updated Catcher’s Mitt Study to account for the commercial build-out of low earth orbit is appropriate?

Answer. The Memorandum of Understanding covers many cooperative areas for orbital debris, including object tracking, space situational awareness, data sharing, and orbital debris mitigation. NASA defers to the DoD on the need for an updated Catcher’s Mitt Study. NASA’s Orbital Debris Program Office continually works with U.S. and international partners to assess growth in Orbital Debris, accounting for recent commercial constellations.

Question 5. Can you provide an update on NASA’s efforts to further investigate the findings related to phosphine on Venus?

Answer. NASA was not involved in the recent study published in *Nature Astronomy* on the subject of phosphine on Venus and cannot comment directly on the findings. However, the Agency trusts in the scientific peer review process and looks forward to the robust discussion that will follow its publication.

Over the past two decades, NASA has made new discoveries that collectively imply an increase of the likelihood of finding life elsewhere. As with an increasing number of planetary bodies, Venus is proving to be an exciting place of discovery, though it had not been a significant part of the search for life because of its extreme temperatures, atmospheric composition, and other factors. Two of the next four candidate missions for NASA’s Discovery Program are focused on Venus, as is the EnVision mission, a proposal (for which NASA is a partner) to ESA’s Cosmic Vision M5 solicitation. Venus also is a planetary destination that can be reached with smaller missions.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JON TESTER TO
HON. JIM BRIDENSTINE

Question 1. During the oversight hearing, in response to a question from Senator Sullivan, you cited the EPSCoR program among the initiatives that NASA is using to inspire the next generation of young Americans to lead NASA into the future. I agree: EPSCoR has made it possible for countless young Montanans to pursue science and technology programs, and I believe many of them will go on to leadership roles at NASA and elsewhere. If we all agree that this successful program is vital to NASA’s future, why does the Administration continue to zero out EPSCoR funding in its budget proposals?

Answer. It is important to understand that NASA’s Science, Technology, Engineering, and Mathematics (STEM) engagement and outreach efforts have always occurred beyond the walls of the Office of STEM Engagement, *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. These are just a few of the STEM activities that NASA employees across the Agency proactively engage on every day. 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 Administration's budget also eliminates the Office of STEM Engagement. In explaining the elimination of these programs, you seem to suggest that the Agency must prioritize Artemis and related mission programs. How should Congress ensure that NASA continues to invest in its long-term sustainability even while achieving inspiring mission success in the coming decade?

Answer. The functional Office of STEM Engagement at NASA Headquarters will continue to oversee Agency-wide strategic direction and coordination of NASA's STEM engagement efforts. A common vision, mission, and strategic goals would continue to drive NASA's future endeavors in STEM engagement. Through Mission Directorate activities, NASA would continue to create unique opportunities for a diverse set of students to contribute to NASA's work; build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content, and facilities; and attract diverse groups of students to STEM through learning opportunities that spark interest and provide connections to NASA's mission and work. NASA's mission and endeavors in exploration and discovery would continue to inspire the next generation to pursue STEM studies.

Question 3. I'm also concerned about the ways in which the Federal contracting process can discourage innovation. If a small company with a great new idea misses out on a contracting round, it might have to close up shop; the big aerospace corporations don't face the same risk. What reforms to the contracting process would you suggest to ensure that small, innovative companies can compete on a level playing field?

Answer. The Office of Procurement, through its authority in the Federal Acquisition Regulation, has always looked for ways to set aside procurements even in the areas of innovation for Small Business. For instance, using the authority under the Small Business Innovation Research Program (SBIR) Program, innovative work has taken place under Contracts awarded under Phases I—III of the Program. Further, NASA has used Broad Agency Announcements (BAA) to award contracts to small companies for innovative work.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JACKY ROSEN TO
HON. JIM BRIDENSTINE

Student Spaceflight Experiments Program. In 2016, Vanderburg Elementary School in Henderson, Nevada was one of eleven schools to have their soybean germination microgravity experiment conducted on the International Space Station (ISS), through the ISS Student Spaceflight Experiments Program (SSEP). It was the first time that a Nevada school had been selected to run an experiment on the ISS, and it offered an invaluable opportunity to engage students in the application of STEM. The success at Vanderburg inspired five schools to submit proposals for their own microgravity experiment in 2018, including Henderson's own Walker Elementary School. A panel of judges selected Walker Elementary's experiment, which flew to the ISS in 2019. These Nevada students and teachers were inspired by the opportunity to put an experiment into space—the creativity, talent, and dedication to the process are invaluable lessons for these budding scientists.

Question 1. How can Congress continue to support the International Space Station (ISS) Student Spaceflight Experiments Program (SSEP) so that more young students can participate in opportunities that excite them to continue their STEM education and pursue STEM fields? Are there opportunities to expand this program so that it can have an even greater reach?

Answer. The Student Spaceflight Experiments Program (SSEP) was launched in June 2010 by the National Center for Earth and Space Science Education (NCESSSE) in strategic partnership with NanoRacks, LLC. STEM payloads typically fly under arrangements with the International Space Station (ISS) National Laboratory operator—the Center for the Advancement of Science in Space (CASIS). Student groups may also go directly to CASIS to be part of their Science, Technology, Engineering, and Mathematics (STEM) activities. Questions regarding these programs should be addressed to SSEP, NCESSSE, and/or CASIS.

STEM on Station, one of NASA's Office of STEM Engagement (OSTEM) Next Generation STEM mission-driven focus areas, is working with collegiate student teams through Student Payload Opportunity with Citizen Science (SPOCS) to fund the design, flight, and return of five student experiments through a partnership with NanoRacks and their sister company, DreamUp.

Question 2. How does NASA conduct outreach and inform schools about this program so that more students can participate?

Answer. Collegiate students were informed of this opportunity through a variety of channels. Social media were leveraged across a variety of NASA flagship Twitter and Facebook accounts to inform students of due dates, and information sessions or subject matter expert panels leading up to proposal submissions. STEM on Station also shared the opportunity among Minority Serving Institutions (MSI), Federal STEM networks, NASA Express, and internal networks to reach a diverse audience.

Reusable Space Planes. The International Space Station (ISS) is currently scheduled to be retired within five years, with a possible extension to the end of the decade. When the ISS retires, NASA plans to contract with commercial companies to help fulfill the science missions currently performed in Low Earth Orbit by the ISS. NASA contractors are currently building reusable space planes that will allow NASA to bring science missions to any major airport in America. This is a big step forward from previously used spacecraft that burn up in the atmosphere or land in the ocean.

Question 1. Could you explain why this kind of reusable capability is important?

Answer. Cost is a driving factor in transportation to and from space. Reusability is an important capability towards reducing the cost of launching and recovering spacecraft. As NASA seeks to expand its partnerships with commercial industry to resupply the ISS, and beyond low-Earth orbit (LEO) under the Artemis program, lower transportation costs will be key to expanding the number of companies and institutions that can participate in space exploration, research, and economic development.

Studies on the impact of microgravity on both living organisms and materials are often interested in the dynamic changes to those samples. Some of these questions are highly sensitive to the change in the gravitational vector (on the timescale of four hours or less), and others struggle to isolate microgravity effects from masking due to the stresses experienced during a high g-force reentry. Vehicles that return samples under a low g-force landing profile and to destinations close to researcher laboratory facilities to quickly analyze results are key to enabling these research capabilities.

Commercial Technologies. Much of the necessary technology and infrastructure needed to return to the Moon does not yet exist. In order to solve these problems, when possible, NASA can procure products or services from commercial companies to foster growth in the domestic space industry. NASA has long invested in the development of commercial services—in fact, since the beginning of the ISS commercial resupply and crew transportation programs, the United States' share of the global commercial launch market has gone from 0 percent in 2011 to 54 percent in 2017.

Question 1. How does NASA plan to work with commercial providers on research, development, and product acquisition for Artemis?

Answer. NASA is partnering with both traditional aerospace contractors as well as other commercial entities and newer market entrants in support of the Artemis program. NASA continues to solicit proposals in a competitive environment, which engenders the most meritorious and cost-effective approaches, as well as preserves leverage for NASA to obtain favorable contract terms and conditions without being unduly burdensome on industry. NASA is utilizing firm fixed price contracts with milestone-based payments in order to maximize contractor incentives to perform efficiently and to control costs and schedule.

For the cislunar Gateway, the development of the Power and Propulsion Element (PPE) will leverage existing industry designs and prior corporate investments, resulting in a demonstration of technologies and capabilities that serve NASA's objectives and that also have numerous other commercial applications.

The Gateway Habitation and Logistics Outpost (HALO) also leverages designs from commercial providers supporting the International Space Station with the Cygnus vehicle. NASA has also contracted for commercial logistics services as a key component in direct support of Gateway resupply.

Further, for the Human Landing System (HLS), NASA is acquiring the development of state-of-the-art capabilities from commercial providers to enable safe, cost-effective transportation of crew to and from the lunar surface. Multiple partners are empowered to propose a variety of unique, innovative systems that the providers will own and operate, as opposed to NASA mandating the development of a specific design solution. After development and demonstration, the HLS providers will continue to retain ownership of these capabilities and, by serving non-NASA customers, will be able to provide cost-effective, safe, and sustainable commercial space transportation services to NASA to and from the lunar surface.

NASA's Lunar Discovery and Exploration Program is working with several American companies to deliver science and technology to the lunar surface through the Commercial Lunar Payload Services (CLPS) initiative. Under the Artemis program, early commercial delivery missions will perform science experiments, test technologies, and demonstrate capabilities to help NASA explore the Moon and prepare for human missions. The first two CLPS launches are targeted for the third quarter of Fiscal Year 2021, with seven total deliveries scheduled between 2021 and 2023. This past June, NASA announced that it had selected a CLPS commercial provider, Astrobotic of Pittsburgh, to deliver NASA's Volatiles Investigating Polar Exploration Rover (VIPER) to a lunar pole in late 2023. By searching for water ice and other potential resources, VIPER will help pave the way for astronaut missions to the lunar surface beginning in 2024, and will bring NASA a step closer to developing a sustainable, long-term presence on the Moon as part of the Agency's Artemis program.

Question 2. And if these public-private partnerships develop, who will ultimately own the product or technology?

Answer. The Gateway is a partnership of multiple space agencies and those agencies will retain ownership of their contributions. For instance, hardware developed under NASA contracts (PPE and HALO) will be transferred to and owned by NASA. However, the logistics resupply of the Gateway will rely on commercially-provided services throughout the Gateway operational lifespan, and the commercial services provider will retain ownership of the capabilities necessary to perform that function for NASA. Finally, after development and demonstration, the HLS providers will continue to retain ownership of their respective capabilities, and NASA will procure landing services from these providers to safely carry crew to and from the lunar surface. Yet HLS also employs a unique data rights regime in which NASA will obtain a Government Purpose Rights license in much of the technology developed under the HLS contract, which will empower NASA to use these technologies on future, non-HLS contracts.

Question 3. Can you talk about the potential practical, earth-based applications for technologies developed by these commercial providers?

Answer. Many technologies necessary for the exploration of the lunar environment also have terrestrial applications. For example, closed-loop life support systems can provide highly efficient water recycling for terrestrial wastewater treatment. Growing crops in space can lead to more intensive farming practices to increase food production. Advanced medical diagnostic and imaging devices needed to ensure crew health on long missions can enhance current telemedicine capabilities. Autonomous lunar rovers for transporting the crew can leverage and improve ground-based autonomous vehicle technologies such as self-driving cars. Finally, lunar surface power systems using solar arrays, fuel cells for energy storage, and autonomous power control could provide technologies for terrestrial smart electrical power grids.

Representation in STEM. With the Artemis program, NASA will put the first woman on the Moon. Incredible women at NASA have paved the way for more women in space, but we still have a huge gap in representation. One of my top priorities in Congress is supporting the STEM workforce and breaking down barriers to success. Last year, the Building Blocks of STEM Act, legislation I introduced with Senator Capito and others on this committee, was signed into law. This initiative focuses on giving our kids, and especially our girls, the opportunities to explore STEM-related fields from an early age. Research has shown it is critical to offer STEM education opportunities when children are young, especially to research historically underrepresented groups. Of those students who eventually work in the Aerospace and Defense workforce, 71 percent of young professionals report they first became interested in these careers during their grade school years.

Question 1. Where is NASA currently seeing its biggest representation gaps, and what are you doing to help increase diversity?

Answer. A review of NASA's mission critical occupations as of October 1, 2020, reveals lower than expected participation rates in certain job series for Females, Males, Asian Americans/Pacific Islanders (AAPI), and White employees as compared to Relevant Civilian Labor Force (RCLF) employment data. The RCLF can be used to measure the diversity of specific occupations based on the availability of workers in the labor force. The Census Bureau defines the RCLF as "the Civilian Labor Force (CLF) data that are directly comparable (or relevant) to the population being considered in the labor force."

NASA is working to recruit a diverse workforce. NASA's innovative recruitment function scales and amplifies resources to promote its brand as an employer and position the Agency to be a leading competitor in attracting the most qualified, diverse talent to meet future mission needs.

One of NASA's FY 2021 goals is to increase workforce diversity by identifying opportunities that attract and target candidates of diverse backgrounds while promoting NASA's workforce inclusion. NASA sees this as a business imperative. Diversity helps attract and retain quality candidates. Studies show that the new generation of job seekers values workplace diversity and looks for companies that place an emphasis on diversity and inclusion, and that younger job seekers are likely to double their average tenure if their employer is committed to diversity, equity, and inclusion.

NASA recruitment highlights and markets diversity as a critical element of NASA's Employer Value Proposition (EVP), aligning with Agency objectives, visually representing and showcasing a diverse employee group in materials, platforms, various special emphasis programs, and employee resource groups. NASA's recruitment efforts also emphasize the teamwork elements of NASA's Unity Campaign and work to welcome all and ensure the Agency is inclusive.

NASA targets diverse talent pools through digital platforms, as well. Recruiters can specifically target diverse audiences through LinkedIn's hiring campaigns as well as through direct contact, and seek to identify and reach out to candidates with similar skills in other industries with greater gender representation.

Question 2. What are other investments should Congress be considering to ensure that today's school-children—particularly those from diverse backgrounds, including women—are well equipped to lead our space exploration workforce?

Answer. NASA has a long history of engaging students in its mission. The scope of STEM Engagement encompasses all endeavors Agency-wide to attract, engage, and educate students and to support educators, educational institutions, and professional organizations. STEM Engagement is comprised of a broad and diverse set of programs, projects, activities, and products developed and implemented by NASA Headquarters functional Offices, Mission Directorates, and Centers.

NASA has made noteworthy progress in implementing operational and systemic changes to further NASA Strategic Objective 3.3.—Inspire and Engage the Public in Aeronautics, Space and Science. In the last two years, NASA has improved the cohesiveness and rigor of its STEM engagement programming and has implemented a new approach for performance measurement, assessment, and evaluation.

NASA actively supports 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 December 2018 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. Congressional support for the goals, pathways, and objectives in this plan is essential to ensuring that all Americans have lifelong access to high-quality STEM education, thereby ensuring that the United States will continue to be the global leader in STEM literacy, innovation, and employment.