

**AN OVERVIEW OF THE NASA BUDGET
FOR FISCAL YEAR 2019**

HEARING
BEFORE THE
SUBCOMMITTEE ON SPACE
COMMITTEE ON SCIENCE, SPACE, AND
TECHNOLOGY
HOUSE OF REPRESENTATIVES
ONE HUNDRED FIFTEENTH CONGRESS
SECOND SESSION

MARCH 7, 2018

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AN OVERVIEW OF THE NASA BUDGET FOR FISCAL YEAR 2019

WEDNESDAY, MARCH 7, 2018

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

The Subcommittee met, pursuant to call, at 10:09 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Babin [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDY BERENICE JOHNSON, Texas
RANKING MEMBER

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House of Representatives
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***An Overview of the National Aeronautics and Space
Administration Budget for Fiscal Year 2019***

Wednesday, March 7, 2018
10:00 a.m.
2318 Rayburn House Office Building

Witnesses

Mr. Robert M. Lightfoot, Jr., Acting Administrator, National Aeronautics
and Space Administration (NASA)

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

Charter

TO: Members, Committee on Science, Space, and Technology
FROM: Majority Staff, Committee on Science, Space, and Technology
DATE: March 7, 2018
SUBJECT: Space Subcommittee Hearing: “An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2019”

On Wednesday, March 7, 2018 at 10:00 a.m. in Room 2318 of the Rayburn House Office Building, the Committee on Science, Space, and Technology, Subcommittee on Space will hold a hearing titled, “An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2019.”

Hearing Purpose

The purpose of the hearing is to review the Administration’s fiscal year 2019 (FY19) budget request for the National Aeronautics and Space Administration (NASA).

Witness

- **Mr. Robert M. Lightfoot, Jr.**, Acting Administrator, National Aeronautics and Space Administration (NASA)

Staff Contact

For questions related to the hearing, please contact Mr. Tom Hammond, Staff Director, Space Subcommittee, or Ms. Sara Ratliff, Policy Assistant, Space Subcommittee, at 202-225-6371.

Chairman BABIN. The Subcommittee on Space will now come to order.

Without objection, the Chair is authorized to declare recesses at any time.

Welcome to today's hearing titled, "An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2019."

I would like to now recognize myself for five minutes for an opening statement.

The passage of the 2017 NASA Transition Authorization Act last year was clear evidence of the Committee's bipartisan support of NASA. The fiscal year 2019 budget request reflects the Administration's adherence to the "continuity of purpose" described in the Authorization Act.

This Committee's commitment to NASA's long-term goals are codified in law and the hearing record we've established over the years. Mars has been, and will remain, the first interplanetary destination for humanity. And along the way, NASA has been encouraged to carry out any mission necessary, including cislunar activities, to advance future interplanetary exploration.

There are many benefits to this strategy. The moon offers a proving ground closer to home for advancing the technologies necessary for deep space exploration. The opportunities for commercial and international participation could greatly enhance a lunar mission. And the more frequent operational cadence will better prepare astronauts, mission crews, and commercial partners for future missions.

We were very encouraged to see the President sign the Space Policy Directive-1 last year and the new Exploration Campaign at NASA in the budget proposal. But the details are still forthcoming, and as a friendly reminder, the Exploration Roadmap called for in the 2017 Authorization Act was due back to this Committee on December the 1st. I hope the Administration will see fit to send this important report soon so that the Committee has the best information to work with.

The President's budget proposal also includes some ideas about the future of the International Space Station. Currently, the ISS will operate until at least 2024, and the budget proposes to end direct government funding in 2025. The idea is that the commercial sector will step in to operate the ISS with NASA as the customer—as a customer I should say.

The ISS, managed and operated out of the Johnson Space Center, it is a unique testbed for deep space exploration and serves as a significant services customer to our developing NASA commercial partners. I remain open to new ideas relative to future operations, but obviously, we need a detailed and realistic, sustainable plan for any ISS transition in the future. We will need buy-in from the industry and the workforce well in advance of simply turning off the lights at the ISS and walking away. Now, I know that isn't what is on the table, but NASA will need to do a better job articulating this plan as we move forward. As another friendly reminder, the ISS transition plan called for the 2017 Authorization Act was also due back to this Committee on December the 1st.

Turning to NASA's science portfolio, this budget request continues to restore balance and support critical work across the entire science directorate. The budget supports a robust science program. This includes a range of small, medium, and large missions, such as the TESS exoplanet mission next month, the Mars Insight lander in May, the Parker Solar Probe over the summer, and the James Webb Space Telescope in 2019, as well as the flagship Europa Clipper and Mars 2020 rover missions, all exciting stuff.

NASA has many exciting projects and missions across the agency. It is amazing to see the progress that's been accomplished over just the last year. Very soon, SLS, Orion, Dragon 2, and Starliner vehicles will take their very first flights. NASA will begin construction of the Deep Space Gateway, the first permanent human outpost beyond low-Earth orbit. And with continued bipartisan congressional support, NASA will continue to make great strides in deep space exploration.

I want to thank Administrator Lightfoot for his testimony, and I look forward to this very important discussion.

[The prepared statement of Chairman Babin follows:]



COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
March 7, 2018

Media Contacts: Thea McDonald, Brandon VerVelde
(202) 225-6371

Statement by Chairman Brian Babin (R-Texas)

An Overview of the NASA Budget for Fiscal Year 2019

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NASA has many exciting projects and missions across the agency. It is amazing to see the progress that's been accomplished just over the last year. Very soon, SLS, Orion, Dragon 2 and Starliner vehicles will take their first flights. NASA will begin construction of the Deep Space Gateway, the first permanent human outpost beyond low-Earth orbit. And with continued bipartisan congressional support, NASA will continue to make great strides in deep space exploration.

I thank Acting Administrator Lightfoot for his testimony and look forward to this discussion.

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Chairman BABIN. I would like to now recognize the Ranking Member, the gentleman from California, for an opening statement.

Mr. BERA. Thank you, Mr. Chairman.

And good morning and welcome to Acting Administrator Lightfoot, and thank you for your strong leadership.

As we look at the budget, we're somewhat happy with the top line numbers. It does suggest the Administration understands the importance of space exploration and funding NASA. But in the 2017 NASA Transition Authorization Act, we talked about NASA being a multi-mission agency and organization. And as we dive into the budget, there are some areas of concern of the overweight focus just on exploration. None of us is going to argue that exploration is not important but we also want to make sure we don't lose sight of the space science side, the space technology, the aeronautics and education.

One area of concern on the space science side is the moving away from the focus on WFIRST. If we think about the objective decadal process, WFIRST was a priority project there. And the decadal survey has served us well. And again, not looking at this scientific-based prioritization and moving away from that certainly can set a dangerous precedent. We don't want to get into a situation where every four years priorities are changing. That makes it very difficult for the NASA Administrator and NASA to focus on some of these longer-term projects.

On aeronautics, cutting back on the X-Plane demonstration. Aeronautics and aviation is an area where America is a world leader, and if we don't continue to maintain that focus and that lead, well, that doesn't just have repercussions on our ability to be the world leader there because others will step into that place, but it does have repercussions on an important segment of our economy. And again, aviation is a \$90 billion positive trade balance for the United States.

In the area of education, the Chairman and I were noticing the number of young people that are out there in the audience, and I think it's great that the students and the young people that are out there have such an interest in space and science and exploration. And the diversity that you see across this audience—and, as the father of a daughter—it is great to see the number of young women in this room as well thinking about science and thinking about the future, so thank you for being here.

But let's not cut the education budget as well because education is incredibly important, particularly programs like the MUREP program, the Minority University Research and Education Program, because the diversity we see in this room, we want to make sure that next generation also reflects the diversity of the United States, so funding programs like that are incredibly important.

And let's touch on exploration. I mean exploration is incredibly important, but as we start to think about—we saw the Space Council wanting to focus on a return to the Moon and the lunar mission. We've talked about that return to the Moon as well. But in truth, a lot of us talk about the desire to go to Mars, and I think my colleague from Colorado certainly will emphasize that.

If we think about our own history and think about when President Kennedy challenged us to put a person on the Moon, we set

a focus and we didn't change every four years. We had some longevity. We understood what that mission and focus was. And if our desire is to go to Mars and go deeper into space, we have to maintain a focus on, you know, how we get there because Mars is going to be tough. It's going to require space technology, it's going to require an investment in space science, it's going to require all the things that NASA does very well, including what the commercial sector can do coming up behind us.

So I'm going to be very interested in hearing your impression, Administrator Lightfoot, but again, I want to make sure that, as we look at NASA as a multi-mission organization, we don't rob from Peter to pay Paul but we actually adequately fund all those missions. And as we go through our budgeting process I think that'll be incredibly important.

[The prepared statement of Mr. Bera follows:]

OPENING STATEMENT
Ranking Member Ami Bera (D-CA)
of the Subcommittee on Space

House Committee on Science, Space, and Technology
 Subcommittee on Space
*“An Overview of the National Aeronautics and Space Administration
 Budget for Fiscal Year 2019”*
 March 7, 2018

Good morning. Welcome Acting Administrator Lightfoot and thank you for your strong leadership of NASA over the past thirteen months. The Fiscal Year (FY) 2019 budget proposal for NASA is about \$19.9 billion. It is worth noting that NASA’s FY 2019 request includes an additional \$300 million to reflect an increase as a result of the 2018 Budget Act agreements. However, starting in FY 2020, NASA’s projected funding lowers to \$19.6 billion and it will be flat-funded in the out-years, losing buying power every year due to inflation. Mr. Chairman, in the context of the overall proposed federal budget, I recognize that \$19.9 billion for FY 2019 is a positive recognition of the important role NASA plays. However, there are some significant proposals in NASA’s budget request that could have profound impact on NASA’s current operations.

Foremost, the impact from establishing Exploration as NASA’s core mission needs careful examination. This is a change from the direction given to NASA just one year ago by the NASA Transition Authorization Act of 2017. That Act which was enacted into law stated that “*NASA should be a multi-mission space agency, and should have a balanced and robust set of core missions in space science, space technology, aeronautics, human space flight and exploration, and education*”. What would a narrower mission for NASA mean?

- In space science, we run the risk of losing U.S leadership in astrophysics by no longer conducting the Astrophysics Decadal Survey’s highest priority mission, WFIRST. Losing leadership would mean that our partner nations may look to other countries, such as China, for collaboration.
- In aeronautics, cutting back the X-plane demonstration program could have serious economic impacts. In 2016, the U.S. had a \$90 billion positive trade balance from aviation, but other countries are catching up. NASA’s X-plane program is needed to keep us ahead.
- And in Education, we would miss out on lifting the skills and enabling the dreams of all Americans by no longer funding programs such as MUREP (Minority University Research and Education Program), EPSCoR (Experimental Program to Stimulate Competitive Research), and Space Grants.

Mr. Chairman, there are other areas that would change under this budget proposal:

The International Space Station is proposed to give way to potential commercialization of the ISS or commercial space stations in low Earth Orbit by 2025. However, Congress cannot fairly assess this proposal because NASA has yet to provide the ISS Transition Plan mandated in

the NASA Transition Authorization Act. In particular, as directed, the ISS Transition Plan is to include metrics that would indicate the commercial space sector's readiness and ability to assume the ISS functions, roles, and responsibilities being transferred.

Exploration priorities would focus immediately on exploring the Moon, first robotically and later by humans. I support lunar exploration, but the impact of this proposal on achieving the goal of humans to Mars cannot be assessed because NASA has yet to provide the Human Exploration Roadmap called for in the NASA Transition Authorization Act. That Roadmap is to include *"information on the phasing of planned intermediate destinations, Mars mission risk areas and potential risk mitigation approaches"*.

Space technology development would be consolidated and become solely focused on Exploration. This comes in conflict with the NASA Transition Authorization Act's assessment of Space Technology, which views such work as enabling *"a new class of Administration missions beyond low-Earth orbit"* as well as research and development of advanced space technologies *"that deliver innovative solutions across the Administration's space exploration and science missions"*. For example, this could mean that the Early Stage NASA Innovative Advanced Concepts initiative could show strong preference for proposals that advance Exploration objectives, rather than strategies and concepts that provide benefits across agency mission areas.

Mr. Chairman, NASA is a critical national asset. For nearly 60 years, it has been a source of technological and scientific innovation, an inspiration to generations of Americans, and a driver of economic growth. I want to work together to do what is necessary to allow NASA to do even greater things. Thank you Mr. Chairman and I yield back.

[The prepared statement of Ms. Johnson follows:]

OPENING STATEMENT

Ranking Member Eddie Bernice Johnson (D-TX)

House Committee on Science, Space, and Technology
Subcommittee on Space

*"An Overview of the National Aeronautics and Space Administration
Budget for Fiscal Year 2019"*

March 7, 2018

Good morning and welcome, Mr. Lightfoot. I would like to begin my remarks by expressing my appreciation for your distinguished service to this nation. As a NASA employee for almost 30 years, and Acting Administrator for the past 13 months, you have personified what I consider to be NASA's greatest strength—its people. The men and women who work at NASA truly are some of America's "best and brightest", and they make the almost impossible look easy—solving challenging problems in aeronautics, science, human spaceflight, and technology while keeping a complex organization running smoothly and fostering an environment that annually makes it one of the Federal government's best places to work.

We in Congress need to do our part to help you do your job, by supplying you with the resources you need in a timely manner. Unfortunately, too often we have failed to meet that basic responsibility, as evidenced by our continuing failure to provide you with your FY 2018 appropriations more than five months into that fiscal year. That is an unacceptable failure of governance that, as you know all too well, Mr. Lightfoot, has a serious impact on NASA's ability to carry out the important tasks the nation has given it.

Unfortunately, I see a similar failure of governance in the President's FY 2019 budget request for NASA. Although accompanied by optimistic rhetoric about assuring America's greatness in space, I'm afraid the reality behind that NASA budget request provides far less grounds for optimism. One only need look at the funding projections to realize that fundamentally this is a budget that has to resort to cannibalizing other NASA important programs to provide the semblance of an Exploration initiative.

Let me be clear. I consider Exploration to be a core mission of NASA, but not the core mission of the agency. As codified in the original 1958 Space Act, NASA has been and should continue to be a multi-mission agency with worthy initiatives in aeronautics, science, technology, and human spaceflight and exploration. NASA's Exploration program challenges us and inspires us and I support it, but I also support NASA's other core missions—missions that advance knowledge and benefit our citizens back here on Earth.

I support Exploration, but I want it to be sustainable. Unfortunately, the President's budget request fails to build a sustainable Exploration program. Why do I say that? Well, when NASA has to completely eliminate its Office of Education, cancel WFIRST—the highest priority mission of the National Academies' Astronomy and Astrophysics Decadal Survey, eliminate important Earth Science missions and instruments, and cut funding for the Aeronautics programs critical to our future competitiveness in aviation, just to give Exploration a small increase in FY 2019 over what it was getting in FY 2017, and then follows that with a lower and flat budget

runout for NASA [i.e., losing purchasing power every year] over the four years that follow, and proposes Exploration funding for the next four years that is lower than that proposed for FY 19, the warning lights are flashing. I could go on to cite other concerns with the President's NASA request, but I think you get the point.

Mr. Chairman, the issues confronting Congress as we review the FY 2019 budget request for NASA are serious and complex. I regret that we are holding this hearing at the subcommittee level instead of letting the full membership of the Committee hear from the Acting Administrator and ask him questions. As you know, NASA's budget is by far the largest of any of the agencies under our jurisdiction and worthy of scrutiny by all our Committee Members. That said, I hope that before we move to reauthorize NASA, this Committee will take the time to hear from all those who will be affected by this budget request. This request raises many issues, including but not limited to: the future of the International Space Station, whether Congress will continue to respect the Decadal Survey process, how best to advance Aeronautics research, and whether the Administration's exploration goals are achievable under its assumed budgets. Let us take the time to thoroughly examine these issues before we legislate, lest we look back in regret at ill-informed decisions made in haste.

With that, I yield back.

Mr. BERA. And Mr. Chairman, I request unanimous consent to submit four documents for the record, including opinion pieces and statements related to NASA's fiscal year 2019 budget proposal.

Chairman BABIN. Without objection.

[The information appears in Appendix II]

Mr. BERA. And I yield back.

Chairman BABIN. Okay. Thank you. I'd also like to—I think I've got the name of the school where you students are from, the Lake Braddock Secondary School from Fairfax, Virginia. Is that correct? Well, welcome this morning. Any other schools participating this morning? Well, anyway, we welcome you. Thank you for being here. And as my friend Dr. Bera said, it's very gratifying to see young folks be interested in STEM studies and our space program. You couldn't find a better place to come and participate and have aspirations to join in at NASA, so thank you for being here.

Let's see. Chairman Smith is not here. Ranking Member Johnson is not here.

Okay. Well, let me introduce the witness today. Our witness today is Mr. Robert Lightfoot, Acting Administrator of the National Aeronautics and Space Administration. Before serving as Acting Administrator, Mr. Lightfoot served as the Associate Administrator, the highest-ranking civil servant at NASA. Before that, he was Director of NASA's Marshall Space Flight Center in Huntsville, Alabama. He managed propulsion, scientific, and space transportation activities.

From 2003 to 2005, he served as Assistant Associate Administrator for the Space Shuttle Program at NASA's headquarters right here in Washington where he oversaw technical and budgetary oversight of the annual budget and initial transition and retirement efforts for the shuttle infrastructure.

From 2005 to 2007, Mr. Lightfoot was responsible for overseeing the manufacture, assembly, and operation of the primary shuttle propulsion elements such as the main engines, solid rocket boosters, and reusable solid rocket motors. We really appreciate all those long years of service.

Mr. Lightfoot received a bachelor's degree in mechanical engineering from the University of Alabama—Roll Tide. He was also named Distinguished Departmental Fellow for the University's Department of Mechanical Engineering in 2007 and was selected as the University of Alabama College of Engineering Fellow in 2009. So I'd like to now recognize Mr. Lightfoot for five minutes to present his testimony.

**TESTIMONY OF ROBERT M. LIGHTFOOT, JR.,
ACTING ADMINISTRATOR,
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION**

Mr. LIGHTFOOT. All right. Thank you, Mr. Chairman and Members of the Committee, for the opportunity to testify before you on the NASA 2019 budget request.

The request places NASA at the forefront of a global effort to advance humanity's future in space and expands on our nation's great capacity for exploration and innovation. NASA is focused on its core exploration mission and the many ways this mission returns

value to the United States. Through this mission, NASA produces knowledge and discoveries, strengthens our economy and security, deepens partnerships with other nations, inspires the next generation, and helps provide solutions to tough problems back here on Earth.

This year's proposal initiates an exploration campaign. NASA will pursue exploration and development of the Moon and deep space by leading innovative new commercial and international partnerships, leveraging and advancing the work we've already been doing in low-Earth orbit on the International Space Station.

Our successful investment with a strong U.S. space industry in low-Earth orbit allows us to focus our energies on farther horizons. As private companies continue their successful cargo missions to low-Earth orbit, we will once again launch astronauts from American soil beginning with test flights this year.

In low-Earth orbit, the International Space Station is our cornerstone of our integrated approach to deep space. We are dedicated to using the full potential of the station to demonstrate critical technologies, learn about human health in space, and focus commercial energies on the growing low-Earth orbit economy. Further, we'll accelerate the process of transitioning to commercial approaches to ensure long-term human presence in LEO by the end of 2024.

In the vicinity of the Moon and on its surface, the Space Launch System and Orion are critical backbone elements to provide us the transportation infrastructure to and from that location. The integrated launch of these systems in fiscal 2020 is on track, and a mission with crew in 2023 remains on track as well. In 2019, we'll have an important test of the Orion Launch Abort System to advance the critical safety knowledge for the upcoming missions.

We'll also begin to build the in-space infrastructure for long-term exploration and development of the Moon. By delivering to the lunar orbit a Power and Propulsion Element as the foundation of our Lunar Orbital Platform Gateway, this gateway will expand what humans can do in the lunar environment and provide opportunities to support those commercial and international missions to the surface that will help pioneer new technologies and exploration.

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

For the deep space domain, technology drives exploration, both human and robotic, and helps us solve problems in space and here on Earth. It lays the groundwork for our future missions and addresses many needs, including how we'll live in space, how we'll get there, and how those technologies will allow us to move further into space. We'll focus our technology investments on applications of the technology to deep space exploration and innovative ways to further our goals from concept to test to flight.

In science, our incredible portfolio will continue to increase understanding of our planet and our place in the universe, pursue civilization-level discoveries such as whether or not there's life elsewhere in the universe, and scout for knowledge to inform future human advancement into space. Our robust activity will include a Mars rover, a lander, sample return missions, diverse Earth and planetary missions, and spacecraft to study the Sun and how it influences the very nature of space. Powerful observations will study other solar systems and their planets and peer back to the dawn of time through other galaxies.

In aeronautics, NASA's work has always strengthened our security and economy, and our ongoing research and testing of new aeronautics technology is critical in these areas. It will help us lead the world in global aviation economy with increasing benefits worldwide. Commercial supersonic flight, unmanned aviation systems, and the next generation of aircraft are some of the critical focuses of this important program to our nation.

Our mission successes will continue to inspire the next generation like the folks with us here today to pursue science, technology, engineering, and mathematics studies to ultimately join us on this journey of discovery and become part of that diverse workforce we will need for tomorrow's critical aerospace careers. We'll use every opportunity to engage learners in our work and our missions.

This budget places NASA again at the forefront of a global effort to advance humanity's future in space and draws on our nation's great capacity for innovation and exploration, to raise the bar of human potential, and improve life across the globe.

Finally, on a personal note, I would like to thank Chairman Smith for his years of service to NASA and this country by his service on this Committee. Thank you very much, and I look forward to your questions.

[The prepared statement of Mr. Lightfoot follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
March 7, 2018

Statement of

Robert M. Lightfoot, Jr.
Acting Administrator
National Aeronautics and Space Administration

before the

House Subcommittee on Space
Committee on Science, Space and Technology
United States House of Representatives

Overview

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

Pursuant to National Space Policy Directive-1, the request provides the FY 2019 resources NASA requires for its role in "an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities." The request provides the resources NASA needs to lead a sustainable campaign of exploration, returning humans to the Moon for long-term exploration and utilization followed by human missions to Mars and other destinations.

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

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

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

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

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

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

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

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

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

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

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

Human Exploration and Operations

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

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

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

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

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

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

Maintaining the ISS requires a fleet of launch vehicles to sustain a constant supply line of both crew and cargo. Under the original Commercial Resupply Services (CRS) contracts, our two commercial cargo partners, Space Exploration Technologies (SpaceX) and Orbital ATK, are providing cargo deliveries to the ISS. Using the space launch vehicles developed in partnership with NASA, SpaceX and Orbital ATK have also helped to bring some of the commercial satellite launch market back to the United States and have reduced commercial launch costs. Under new CRS-2 contracts, SpaceX, Orbital ATK, and Sierra Nevada Corporation will deliver critical science, research, and technology demonstrations to the ISS over five years from 2020 through 2024. Working with our commercial crew partners, SpaceX and the Boeing Company, NASA plans to return crew launch capability to American soil in 2018. The FY 2019 request provides critical resources in this exciting and challenging period as we work with our partners to launch the first new U.S. human spaceflight capability in a generation.

Under the auspices of the ISS National Laboratory, managed by the Center for the Advancement of Science In Space (CASIS), NASA and CASIS continue to expand research on the ISS sponsored by pharmaceutical, technology, consumer product, and other industries, as well as by other Government agencies, such as the National Institutes of Health and the National Science Foundation. Through CASIS' efforts, the ISS National Lab has reached full capacity for allocated crew time and upmass and downmass.

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

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

SLS, Orion, and EGS are the critical capabilities for maintaining and extending U.S. human spaceflight leadership beyond LEO to the Moon, Mars, and beyond. In FY 2018, SLS Core Stage integration and outfitting (including installation of the four RS-25 engines) will continue at Michoud Assembly Facility. There will be a series of EM-1 flight hardware deliveries to EGS at Kennedy Space Center (KSC). SLS will prepare for the EM-1 Design Certification Review planned for early 2019, conduct the Critical Design Review (CDR) for the next mission, EM-2, and begin fabrication of components for EM-3 and beyond. In FY 2018, Orion will continue qualification testing of systems for EM-2. NASA is accelerating the ascent abort-2 test (AA-2) into 2019, ahead of EM-1. Structural work is already underway on Orion EM-2 flight hardware production. For EM-1, the European Service Module is

scheduled to be delivered to the Operations and Checkout Building at KSC for integration with the Crew Module. Later this year, EGS will complete the system verification and validation phase and begin the operations and integration phase in preparation for multi-element verification and validation for the Mobile Launcher, Pad, and Vehicle Assembly Building. These are the early steps on a journey that leads American astronauts into deep space, permanently.

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

NASA is also working on the second phase of the Next Space Technologies for Exploration Partnerships (NextSTEP), an effort to stimulate deep-space capability development across the aerospace industry. Through these initial public-private partnerships, NextSTEP partners will provide advanced concept studies, technology development projects, and significant measurements in key areas, including habitat concepts, environmental control and life support systems, advanced in-space propulsion, and small spacecraft to conduct missions related to strategic knowledge gaps. NASA intends to perform integrated ground testing using habitation capabilities developed by the NextSTEP partners in 2018.

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

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

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

NASA's FY 2019 request includes \$1.0 billion for Exploration Research and Technology to conduct research to address needs for human and robotic space exploration and to foster commercial expansion in LEO, cislunar space, and beyond. Technology drives exploration by spanning the Technology Readiness Level spectrum, including investments in early-stage concepts and prototypes. Exploration Research and Technology key areas of focus will include:

- Advanced environmental control and life support systems;
- In-Situ Resource Utilization (ISRU);
- Power and propulsion technologies for exploration;
- Advanced communications, navigation, and avionics;
- In-space manufacturing and on-orbit assembly;
- Advanced materials;
- Entry, Descent, and Landing;
- Autonomous operations; and
- Research to enable humans to safely and effectively operate in various space environments.

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

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

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

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

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

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

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

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

Science

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

The budget integrates science and human exploration goals, including the eventual return of humans to the Moon. Just this past year, scientists used data from NASA's Lunar Reconnaissance Orbiter to identify areas in lunar craters that are cold enough to have frost present on the surface – ice that could provide crucial resources for exploration while also containing valuable information about the chemical makeup of the early solar system. Establishing a new Agency-wide Lunar Discovery and Exploration program and leveraging NASA's extensive lunar science experience and data, this budget jump-starts commercial partnerships, innovative approaches for building and launching next-generation precision science instruments, and the development of small rovers that will reach the Moon's surface via commercial landers.

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

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

NASA's Planetary Science program develops and operates missions that explore our solar system and search for life elsewhere, helping to answer fundamental questions about our place in the universe. NASA's Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) lander is being prepared for a May 2018 launch, and will land on Mars in November – joining a series of NASA rovers, landers, and orbiters already at the Red Planet. InSight's advanced payload will provide unique information on the interior structure of Mars, providing glimpses into the processes that shaped the rocky planets of the inner solar system. The budget also enables essential progress to be made on the Mars 2020 rover and planning for a potential Mars Sample Return mission incorporating commercial and international partnerships – a top priority identified by the scientific community in the most recent planetary decadal survey.

In the coming year, NASA's Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx) mission will arrive at the asteroid Bennu later this year, providing unique data that will shed light on the early history of the solar system. OSIRIS-REx measurements of the composition of the potentially hazardous Bennu will also inform the design of future missions to mitigate asteroid impacts on Earth, an effort aligned with and supporting NASA's new Planetary Defense program. During 2018, NASA will continue development of the cutting-edge Europa Clipper mission to fly by Jupiter's ocean moon, and will announce the next scientifically and technologically innovative New Frontiers mission: either a comet sample return or a drone to explore Saturn's largest moon, Titan.

NASA's Astrophysics program investigates the creation and evolution of the universe and the formation of planetary systems. It examines how environments hospitable for life develop, and contributes to the search for the signature of life on other worlds. The program operates the Hubble, Chandra, Spitzer, Fermi, Kepler, and Swift space telescopes, flies the airborne Stratospheric Observatory for Infrared Astronomy (SOFIA), and conducts balloon and suborbital rocket campaigns. NASA's impressive observatories will soon be joined by the James Webb Space Telescope, which is progressing toward a 2019 launch. Webb will be larger and more powerful than any previous space telescope. It will be capable of examining the first stars and galaxies that formed, viewing the atmospheres of nearby planets outside our solar system, and informing our understanding of the evolution of our own solar system.

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

NASA's Heliophysics program studies how the Sun affects the Earth and objects around it, how it influences other planets in the solar system, and how our star affects the very nature of space itself. Improved understanding of the Sun and information about the space weather phenomena it produces is used to provide warnings and better protect lives and essential – but vulnerable – systems on Earth, as well to safeguard astronauts, satellites, and robotic missions traveling through the solar system. The budget supports efficient, continued operation and analysis of data from the Solar Dynamics Observatory (SDO), the joint European Space Agency (ESA)-NASA Solar and Heliospheric Observatory (SOHO), and the Solar and Terrestrial Relations Observatory (STEREO). Together, they constantly monitor the Sun, revealing coronal mass ejections and releases of solar energetic particles, while also advancing scientific understanding of our star's fundamental dynamics. Focusing closer to Earth, the Magnetospheric Multiscale (MMS) mission uses four small spacecraft flying in formation to gather information on Earth's magnetic environment, changing our understanding of how that environment protects our planet.

Heliophysics is preparing the launch of several innovative missions. The Global-scale Observations of the Limb and Disk (GOLD) instrument was launched aboard a commercial communications satellite in January 2018, and the Ionospheric Connection Explorer (ICON) spacecraft launches later in 2018. Together, they will provide the most comprehensive observations of the ionosphere – a region of charged particles in Earth's upper atmosphere – ever achieved. NASA and the National Oceanic and Atmospheric Administration (NOAA) are exploring a potential partnership to use a single launch vehicle for the Interstellar Mapping Probe (IMAP) (the highest priority in the Heliophysics decadal survey) and a NOAA space weather monitoring payload. The partnership would provide NOAA access to the L1 Lagrange point for future space weather monitoring. The Space Environment Testbed 1 mission, a technology demonstration mission developed in partnership with the United States Air Force, is scheduled for launch in 2018, and three heliophysics CubeSats are being prepared for launch as part of NASA's CubeSat Launch Initiative. Perhaps most exciting is the upcoming launch of the Parker Solar Probe, scheduled for August 2018. This historic mission will be the first to travel through the Sun's atmosphere, providing humanity with the closest-ever observations of a star.

NASA's Joint Agency Satellite Program brings NASA's best practices to bear to support our interagency customer NOAA in the development of critical weather satellites for the Nation. Geostationary Operational Environment Satellite-R (GOES-R, now GOES-16) transitioned to NOAA operations in June 2017, and Joint Polar Satellite System-1 (JPSS-1, now NOAA-20) successfully launched in November 2017.

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

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

In August and September 2017, data products from NASA Earth-observing research satellites were used to support real-time decision-making and response efforts by the Federal Emergency Management Agency, other operational agencies, and first responders on the ground in the affected areas during the catastrophic landfalls of hurricanes Harvey, Irma, and Maria. Precise, broad-coverage observations from NASA's Global Precipitation Measurement (GPM) Core Observatory enabled forecasters to understand and track the storms, and to generate accurate flood predictions. A suite of NASA satellite missions, including the Soil Moisture Active Passive (SMAP) satellite, assisted with flood mapping and recovery planning.

NASA's Earth Science program is pioneering innovative partnerships and mission strategies to achieve science goals rapidly and cost-effectively. The budget accelerates NASA's pilot data buys and evaluations of data products from commercial, on-orbit small-satellite constellations; NASA will have Blanket Purchase Agreements with at least four private-sector small-satellite data providers in place by Spring 2018. The low-cost, competitively-selected ECOSystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) instrument to measure agricultural water use in the United States and vegetation stress around the globe, and to identify drought warning conditions, will launch to the ISS in mid-2018. Two major competitively selected payloads – Tropospheric Emissions: Monitoring of Pollution (TEMPO) to measure North American air quality, and Geostationary Carbon Cycle Observatory (GeoCarb) to measure natural carbon flux processes in the western hemisphere – are being developed for flight as hosted payloads on commercial communications satellites in this budget.

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

Launching in 2018, two important decadal-survey-recommended missions will expand the long-term collection of key Earth observations. Making precise measurements of gravity from two spacecraft, the GRACE Follow-On mission (a partnership with German research and space agencies, launching in Spring 2018) will provide global information on ice sheet and oceanic mass balances, underground water storage changes in aquifers, and regional drought conditions. The Ice, Cloud and land Elevation Satellite-2 (ICESat-2), the follow-on to NASA's ICESat and IceBridge missions, will launch in Fall 2018 to map and monitor land ice topography and glacier flow, sea ice thickness, and the heights of the vegetation canopy at low- and mid-latitudes across the globe. NASA remains on track to launch Landsat-9 in December, 2020 to continue the critical land imaging series begun with our United States Geological Survey (USGS) partners in 1972. Consistent with the FY 2018 budget, the FY 2019 budget proposes to terminate OCO-3, DSCOVR Earth-viewing instruments, and CLARREO Pathfinder.

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

Aeronautics

NASA's Aeronautics Research program advances U.S. global leadership by developing and transferring key enabling technologies to make aviation safer, more efficient, and more environmentally friendly. With a request of \$634 million for Aeronautics, the FY 2019 budget invests in the most critical concepts and technologies required to support continued global leadership in civil aviation.

In the coming weeks 2018, NASA will award a competitive contract for detailed aircraft design, build, and validation of the Low Boom Flight Demonstrator (LBFD) X-Plane that will demonstrate quiet overland supersonic flight and enable U.S. industry to open a new market to U.S. industry. In FY 2019, NASA will ensure the LBFD X-plane is on track for first flight by FY 2021. NASA also will continue to develop and validate community response test methodologies which will be employed during the subsequent LBFD flight campaign. Data generated from flights of this demonstrator will feed directly into national and international regulatory decision making processes and timelines, enabling a rule change that will allow civil supersonic flight over land. NASA will also continue to advance new subsonic aircraft technologies that will dramatically reduce fuel consumption, noise, and emissions through a combination of numerical analyses, ground tests, and flight experiments.

NASA's request for Aeronautics will invest in developing revolutionary tools and technologies ranging from hybrid and all-electric aircraft, autonomy, advanced composite materials and structures, data mining, verification and validation of complex systems, and revolutionary vertical lift vehicles, to enabling further advances for transformative vehicle and propulsion concepts that will address a broad array of our aviation industry's needs. In partnership with industry, NASA will complete the Advanced Composites project, delivering a variety of computational tools and guidance that will significantly reduce the time needed to develop and certify new composite structures for aerospace applications.

NASA will advance electric propulsion systems by flight testing an advanced configuration of the X-57 Maxwell aircraft, a general-aviation-scale aircraft to test highly integrated distributed electric propulsion technology. This demonstration will address the integration of electrical and power distribution components, critical to development of standards and certification methodologies required to enable widespread use of this technology. NASA also will advance the state of the art of key technologies needed to realize practical larger-scale hybrid electric propulsion systems for the future.

NASA will demonstrate new air traffic management (ATM) tools that integrate aircraft arrival, departure, and airport surface operations to reduce flight delays and increase air traffic capacity and safety, supporting realization of the Federal Aviation Administration's (FAA's) full vision for the Next Generation Air Transportation System (NextGen). Even with limited operational trials at the Charlotte Douglas International Airport, technologies being developed by the ATM Technology Demonstration-2 Project is already showing significant savings in fuel burns and delays during taxi operations. NASA will accelerate development and complete the transfer to FAA of key weather-related technologies for efficient enroute operations. NASA will explore new, innovative solutions for proactively mitigating the risks of using new vehicle technologies, leveraging the recently published National Research Council study on In-Time Aviation Safety Management as well as partnerships with the FAA and aviation industry. In FY 2019, NASA will demonstrate and validate tools which can be used for safety assessment of ATM and avionics systems, and transfer them to the FAA and the avionics industry.

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

NASA's FY 2019 request increases funding for hypersonic fundamental research which will enable development of tools and methods to more efficiently design future hypersonic vehicles.

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

Education

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

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

Mission Support

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

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

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

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

Conclusion

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

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

National Aeronautics and
Space Administration
NASA Headquarters
Washington, DC 20546



Robert M. Lightfoot, Jr.
Administrator (Acting), NASA Headquarters



Robert M. Lightfoot Jr. became NASA's Acting Administrator effective January 20, 2017. His permanent title is Associate Administrator for NASA, the Agency's highest-ranking civil servant position, effective since September 25, 2012.

He previously was director of NASA's Marshall Space Flight Center in Huntsville, Ala. Named to the position in August 2009, he headed one of NASA's largest field installations, which plays a critical role in NASA's space operations, exploration and science missions. Lightfoot managed a broad range of propulsion, scientific and space transportation activities contributing to the nation's space program. He served as acting director of the center from March 2009 until his appointment as director.

From 2007 to 2009, Lightfoot was deputy director of the Marshall Center. Lightfoot served as manager of the Space Shuttle Propulsion Office at Marshall from 2005 to 2007, where he was responsible for overseeing the manufacture, assembly and operation of the primary shuttle propulsion elements: the main engines, external tank, solid rocket boosters and reusable solid rocket motors.

From 2003 to 2005, he served as assistant associate administrator for the Space Shuttle Program in the Office of Space Operations at NASA Headquarters in Washington. His responsibilities included space shuttle return to flight activities following the Columbia tragedy, technical and budgetary oversight of the \$3 billion annual budget and initial transition and retirement efforts for shuttle infrastructure.

In 2002, Lightfoot was named director of the Propulsion Test Directorate at NASA's Stennis Space Center. He served as deputy director of the organization beginning in 2001, until his appointment as director.

Lightfoot began his NASA career at the Marshall Center in 1989 as a test engineer and program manager for the space shuttle main engine technology test bed program and the Russian RD-180 engine testing program for the Atlas launch vehicle program.

Lightfoot received a bachelor's degree in mechanical engineering in 1986 from the University of Alabama. In October 2007, he was named Distinguished Departmental Fellow for the University of Alabama, Department of Mechanical Engineering. He was selected as a University of Alabama College of Engineering fellow in 2009. Lightfoot serves on the University of Alabama Mechanical Engineering Advisory Board. In 2010, he was inducted into the State of Alabama Engineering Hall of Fame.

Lightfoot has received numerous awards during his NASA career, including a NASA Outstanding Leadership medal in 2007 for exemplary leadership of the Shuttle Propulsion Office, assuring safety for the return to flight of the space shuttle. In 2006, he was awarded the Presidential Rank Award for Meritorious Executives, and in 2010 and 2016, he received the Presidential Rank Award for Distinguished Executives - the highest honors attainable for federal government work. In 2000, Mr. Lightfoot received a Spaceflight Leadership Recognition Award, which recognizes leaders who exemplify characteristics necessary for success. In 1999, NASA's astronaut corps presented him with a Silver Snoopy Award, which honors individuals who have made key contributions to the success of human spaceflight missions. He also received the NASA Exceptional Achievement Medal in 1996 for significant contributions to NASA's mission.

Chairman BABIN. Thank you very much. I'd like to recognize myself for five minutes for questioning.

The National Academies Pathways report from 2014 included a sand chart that depicted the notional budget for exploration, so I would ask if you wouldn't mind, please pull up that chart.

[Slide.]

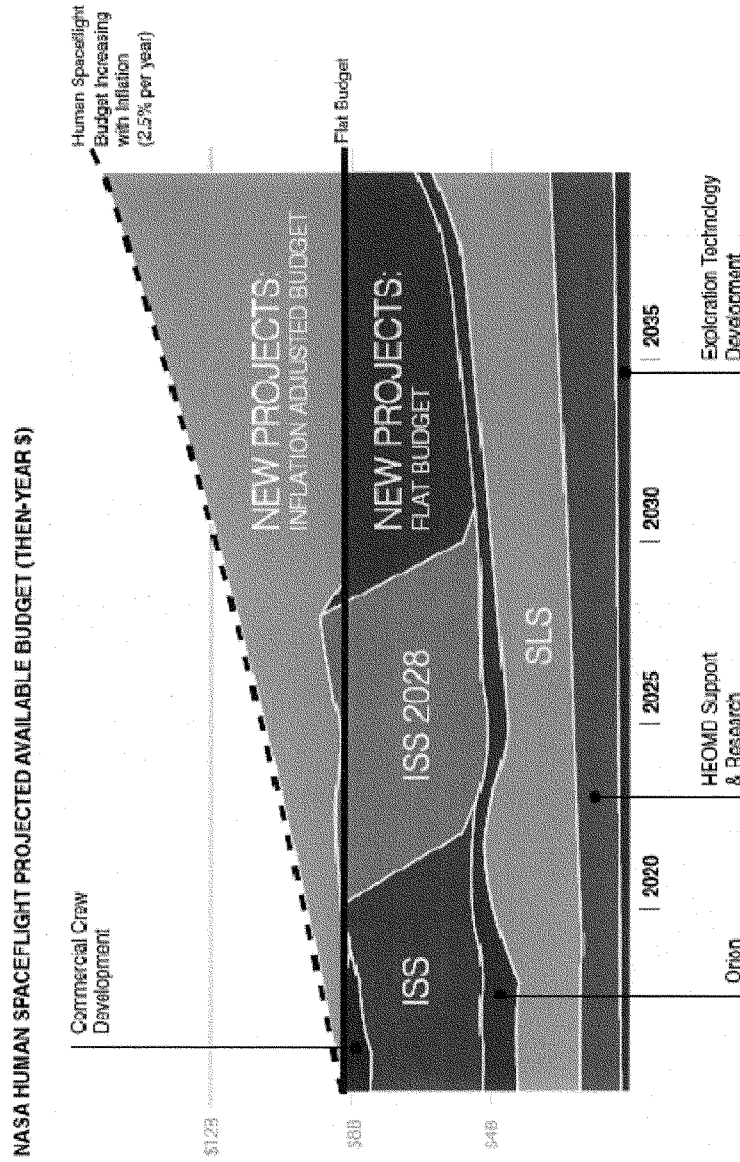


FIGURE 4.29 Projected available budget and costs of the currently planned human spaceflight program.

National Academies 2014 report, "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration."

NASA HUMAN SPACEFLIGHT PROJECTED AVAILABLE BUDGET (THEN-YEAR \$)

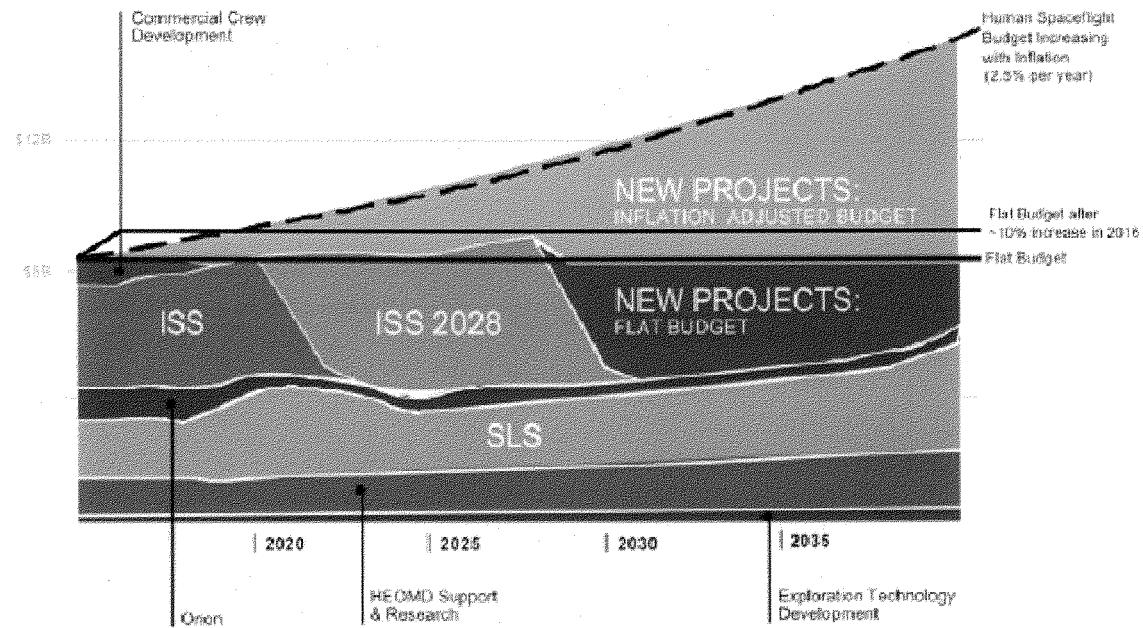


Figure 4.29m, with enacted levels in 2016 (modified by M. L. Dittmar) Used by permission.

Testimony before the House Science, Space, and Technology Committee hearing titled "ISS After 2024," Mary Lynne Dittmar, Executive Director, Coalition for Deep Space Exploration, March 22, 2017.

Chairman BABIN. Thank you very much. The chart broke down funding for the ISS, for the SLS, Orion, as well as exploration technology and research, and the chart visualizes how, without significant increases to the exploration budget, the development of any new projects going forward would be delayed in order to accommodate the continued operation of the ISS on to 2028.

Last March, this Subcommittee held a hearing on the plans for the ISS after 2024, and at the hearing, we heard testimony about how slight increases to the exploration budget have allowed for some bit of flexibility to these projections. So I'd ask you to pull up the second chart if you would.

[Slide.]

Chairman BABIN. NASA's exploration budget request for fiscal year 2019 is \$10.5 billion, and while this is considerably more than was envisioned in the Pathways report, that \$10.5 billion now includes approximately \$1 billion in activities previously funded under the Space Technology Mission Directorate. So let's assume that budget caps are not lifted significantly in the future. If the ISS is extended past the current authorized date of 2024, what new projects will be delayed, and would the Lunar Orbital Platform-Gateway be delayed? Would it prevent the start of a human lunar excursion vehicle development until after the 2030s?

Mr. LIGHTFOOT. Well, I think if you look at the budget request we have, it—and we're proposing to eliminate government funding for the ISS in 2025.

Chairman BABIN. Right.

Mr. LIGHTFOOT. That's our intent is to get—so we don't have to fund that in the future and so that the total program, though, when you look at it, what we want to do is work the Mars vicinity. We want to get the platform built. We want to build these robotic landers to and from the Moon. There—while it's not a perfect transition from what we're doing in low-Earth orbit, there's not like a switch we're going to flip and magically go there—

Chairman BABIN. Right.

Mr. LIGHTFOOT. —right? What we want to use now this year, this budget year is to go determine what are the commercial capabilities that would allow us to fill the gap that you show in your chart after 2024. What would they—what capabilities are going to be there? So you're going to see a series of announcements from us. We're trying to stimulate that with \$150 million in this 2019 budget and roughly if—you know, in the out years that would be \$900 million over time to see who can fill that slot so we can move on and build those Gateway pieces.

Chairman BABIN. Okay.

Mr. LIGHTFOOT. That's the way we're looking at it.

Chairman BABIN. Okay. Thank you. And then second, if NASA transitions low-Earth orbit operations to the private sector, how will NASA preserve the unique expertise and capabilities related to mission operations, program management, systems integration, including habitat and astronaut training, among other core competencies that reside at Johnson Space Center? Is there a long-term strategic plan that clearly delineates core center roles? And for the past several years, every time we've asked headquarters,

the answer has been we need to wait and see. So what say you about that?

Mr. LIGHTFOOT. Yes, we've spent quite a bit of time in the last two or three years defining center roles and what the roles are and of course JSC, Johnson Space Center, has those roles that you described. We believe those roles continue as we move into the—

Chairman BABIN. Okay.

Mr. LIGHTFOOT. —lunar platform, and we also—one of the other things we want to learn from the request for the commercial folks this upcoming year is what capabilities do they want to depend on? Because mission operations—

Chairman BABIN. Yes.

Mr. LIGHTFOOT. —astronaut training, those are things we can offer and then get reimbursed for as we move forward.

Chairman BABIN. Right. Okay. Thank you.

A backup plan for commercial crew, when the commercial crew partners experienced delays two years ago, NASA was able to maintain U.S. access to the station through the purchase of additional Soyuz seats through Boeing as a result of their Sea Launch settlement. Additional delays announced at their hearing earlier this year once again threaten U.S. access to the ISS. There are no more Soyuz seats to buy. Is NASA considering accepting additional risk by flying U.S. astronauts on commercial crew test flights? And if additional delays occur this spring, which is not out of the question given the complexity of work over the next several weeks, is this risky option off the table? And are we in a position that we may need to scale back crew on the ISS? Will we have to frontload our agreement with the Russians to maintain a steady crew in the near term, which will end up costing us more in the out years to accommodate their cosmonauts on commercial providers? I know I'm trying to get these questions in before I run out, so if you could answer some of those, I'd appreciate it.

Mr. LIGHTFOOT. Yes, so in the spirit of time here, what I—we are looking at several options along that line.

Chairman BABIN. Right.

Mr. LIGHTFOOT. I can tell you that we're working with the Russians, we're working with our commercial partners, but we maintain—we're still confident our commercial providers are going to provide us the capability we need, and we're just looking at contingencies in case it happens. What I would offer is our teams can come up and brief you on the different options we're looking at—

Chairman BABIN. Right.

Mr. LIGHTFOOT. —at some point, brief your staff on that.

Chairman BABIN. Okay. Great. That's good. And I'm out of time, so I would like to recognize Mr. Bera now.

Mr. BERA. Thank you, Mr. Chairman.

Administrator Lightfoot, what's the basis for NASA focusing in on a core mission of exploration, specifically lunar exploration, when successive of NASA Authorization Acts have emphasized the multi-mission role of NASA?

Mr. LIGHTFOOT. Yes, I think what we're looking at—I think we still have a very balanced budget when you look across the multi-mission opportunities in science and aeronautics and technology, along with the exploration activity. What we're really trying to do

here is focus on a long-term plan with our eye on Mars ultimately, right, but we had to really start to define—and this Committee has even asked us to do that multiple times. We had to define what we're going to do in the decade of the 2020s to get ready to go to Mars. And I think what you see in this budget is a series of missions to the Moon and the lunar vicinity that are going to enable us to get to Mars ultimately. So I think we still have a good balanced budget from that standpoint.

Mr. BERA. And as we look at that return to a lunar mission, I think we've talked about this on this Committee multiple times, that that return has to be in the context of learning something new that allows us to go on to the next capabilities. I know we've asked for that human exploration roadmap that talks about these interim destinations that allow us to go further. Without that roadmap it becomes difficult for us to evaluate kind of the exploration campaign. When do you think we're going to get that roadmap?

Mr. LIGHTFOOT. You could should get it by the end of the month.

Mr. BERA. By the end of this month, okay. In my opening statement I expressed some concerns about robbing Peter to pay Paul and, again, the concerns of not having as well-rounded a multi-mission portfolio. What are the short-term and long-term impacts of giving human exploration precedence over other priorities that were outlined in multiple decadal surveys?

Mr. LIGHTFOOT. Yes, I think when you look at the priorities that we have today, we're still meeting the majority of our science priorities going forward. We're going to launch TESS, for instance, this upcoming year. We've got James Webb going out, so the astrophysics area is in pretty good shape from that standpoint. We'd like to look at more integration between our human exploration and science missions, and so when you look at the lunar activity we're doing, it's not just lunar science that we're looking at. We're looking at other science we can do from the area of the Moon to meet the objectives—meet the objectives in maybe different ways than we have in the past that are in the decadal. So our science team is looking at that as we go forward.

Mr. BERA. Okay. I made reference in my opening statement that in the '60s when we challenged ourselves to put a person on the Moon, the focus of the mission didn't change from one Administration to the next. You had both Democratic and Republican Presidents focused on that Apollo mission. And I do think there is some concern as we go from one Administration to another I'd be curious from the NASA perspective, it's got to be difficult as you're trying to plan these longer-term missions that focus changes from one Administration to another.

And how can we in Congress—we don't tend to turn over every four years. Hopefully, some of us are here for a while to help guide that process along. And again, we recognize it is Congress' job, it's the House's job to set the budget priorities and give you that budget, and your job as Administrator is to implement that budget. What are some things that we can do to avoid a shift every four years but allow you to do your job of focusing in on that mission to Mars in 2033? Does that make sense?

Mr. LIGHTFOOT. Yes, I think from our end we think that this particular budget proposal just provides some clarity and context in

terms of trying to still get to Mars as an out—you know, kind of that horizon goal that we talked about before. And what we're seeing is that we can use the lunar vicinity and lunar surface, a more detailed and a more—a better understanding of what we can do there to actually help us go there. The Gateway is a critical piece of this. We are not just going to the Moon. We're going to the lunar vicinity. We believe the Gateway can also be a launching point to go to Mars, but we've got to build it first, right?

So we haven't really—it's not as big a change in my mind as maybe it looks like overall in terms of the exploration planning, but what you guys can do is what you always do, is hold us accountable to make sure we're doing the same things that you want us to do from an overall perspective.

I will tell you multi-decadal missions like we're talking about doing here are difficult in one-year increments——

Mr. BERA. Right.

Mr. LIGHTFOOT. —right, and that continuity and that—is very important to us to—for us to keep going as well, not just from the policy standpoint but from the budgeting perspective.

Mr. BERA. And so since it's our job to hold you accountable, do you feel the budget, as proposed, will give you enough of that multi-mission focus and enough of that multi-decadal focus to continue focusing in on that long-term mission?

Mr. LIGHTFOOT. Absolutely.

Mr. BERA. Okay. Thank you. And I'll yield back.

Chairman BABIN. Thank you, Mr. Bera.

I'd like to recognize the gentleman from Alabama, Mr. Brooks.

Mr. BROOKS. Thank you, Mr. Chairman.

And I'd like to congratulate you, Mr. Lightfoot, on once again today setting a new record as the longest-serving Acting Director of NASA. I hope you'll have an extension of that record tomorrow. We'll see if the Senate ever acts on who's supposed to be nominated by the President.

Now, how much steel and aluminum does NASA use? Do you have any judgment about that?

Mr. LIGHTFOOT. I have no idea, sir.

Mr. BROOKS. Well, I mean you use steel in the launch platforms and of course aluminum. That's one of the metals used in alloys or directly in providing lightweight launch vehicles, commercial crew vehicles, all those things, correct?

Mr. LIGHTFOOT. It's usually different material for that. I mean, we use a lot of aluminum I'm sure. I can't tell you how much, though.

Mr. BROOKS. Has this Administration's proposed NASA budget taken into account the higher cost for steel and aluminum that would be anticipated because of the proposed ten percent aluminum and 25 percent steel tariffs?

Mr. LIGHTFOOT. No.

Mr. BROOKS. All right. I hope——

Mr. LIGHTFOOT. It was developed before that so——

Mr. BROOKS. Okay. I hope you'll take that into account, and hopefully it will be minimal, but if it's not and it's something we need to adjust for, then we do need that information.

In March of last year, the Committee held a hearing on the future of the International Space Station. More recently, the President's budget proposes additional funding to stimulate low-Earth orbit commercialization. Would you please discuss NASA's current thinking on commercialization and transition strategies for the International Space Station?

Mr. LIGHTFOOT. Yes, sir. We think that the commercial industry is really on the precipice of really being able to take over that area. We need another destination perhaps other than ISS or use the International Space Station as a destination maybe operated by others. Our planning and our thoughts here are that if we're going to do this, we need to talk about it now and not later on if we're going to—because of the way the budget works. We—so what we want to do this year is we want to do a series of calls for—to see what people are doing, ask for their business plan, their business proposal, what are they going to do, whether it's use the ISS, have a standalone activity in low-Earth orbit, but ultimately develop a destination in low-Earth orbit that our commercial partners can go to that we and our international partners can use going forward.

Mr. BROOKS. If NASA is unable to reduce its cost for operating the International Space Station by 2025, and if the low-Earth orbit commercialization activity does not bear fruit, what should the United States do regarding its presence on the International Space Station at that point?

Mr. LIGHTFOOT. Yes, I think the real question is what is the research we can get, the research and science value in low-Earth orbit that we will get from an International Space Station or another entity. And I think that's a discussion we'll have once we get the data back that tells us what we need to go do, and we'll bring back a budget that addresses it. We'll have to make that decision based on the technologies and the research that we need to do whether we can accomplish it in low-Earth orbit or in our future move out to the toward the Moon.

Mr. BROOKS. Each commercial crew provider is required to fly an un-crewed flight followed by a crewed test flight before beginning International Space Station crew missions. Originally, commercial crew providers were required to fly functioning environmental control and life-support systems on their un-crewed flights. These systems provide oxygen to astronauts, absorb carbon dioxide, provide heating and cooling for the crew, and maintain atmospheric pressure.

Recently, SpaceX was granted a waiver by NASA to fly their first test flight without these systems. What is NASA's reasoning for skipping this stage? And that's assuming the information I have is correct. First, is the information I have correct?

Mr. LIGHTFOOT. I'm not 100 percent sure, but what I will tell you is no matter what we do when we fly crew, we'll have the safety policy in place that we need, and we'll have the risk management appropriately around those activities. So I'll take that for the record to get back with you in terms of exactly what we've agreed to there on that—from that standpoint. But no matter what the first crewed flight is for us, it will have the right safety checks that we would normally do and require before we fly crews on those missions.

Mr. BROOKS. Well, thank you. I look forward to getting that information back and also if the proposed tariffs on aluminum still do affect the NASA's budget, if you could get that back to us, too, so that we can assure that NASA's properly funded.

Mr. LIGHTFOOT. Okay.

Mr. BROOKS. Thank you.

Chairman BABIN. Thank you.

I'd like to recognize the gentleman from Colorado, Mr. Perlmutter.

Mr. PERLMUTTER. Thank you, Dr. Babin.

Mr. Lightfoot, thank you for your service. Thanks for sitting and staying in this position as Acting Administrator. You've been doing it for a long time. You were Associate Administrator before that. Just in a few words, is it time to have somebody who's permanent in that position? Is it hard as an Acting Administrator to move the agency forward?

Mr. LIGHTFOOT. I think, you know, from my perspective on that, as someone sitting in that chair, it is always of value to have the person the President wants in this position, and I think that would be important for us all from that standpoint. But I can tell you for the past year I've had no trouble having access to the people I need to have access to. I've been involved—I mean, I've been to both Space Councils. I've had a chair—I haven't had to sit in the back row. I've sat right at the table, as the Administrator would be, but there is value in having the approved presidential nominee in the chair.

Mr. PERLMUTTER. Okay. Well, thank you. I don't know if the students over here, are you from Lake Braddock? Okay. So I know a lot of your classmates just left, but I'm just curious. Of you all, any of you plan to be astronauts or work in the space program? By a show of hands, I'd be curious. You're all going to be doctors in the healthcare business, right? All right.

Well, I'm sorry the rest of them left because I'm a lawyer; I'm not a scientist. I'm not any of that, but I watch—I love science fiction—*Star Wars* and *Star Trek* and *Men in Black* and *Back to the Future*. So some of what we're doing here reminds me of *Back to the Future*, a real effort on exploration, a real desire to do that, but when we were in the '60s, there was a real investment in getting to the Moon or, you know, as the Administrator knows, I want to get our astronauts to Mars by 2033, which the orbits of Mars and Earth are close, and it saves a lot of space travel and potential danger to our astronauts.

But I guess, Mr. Administrator, my question is this: There is an emphasis on exploration, but it seems to be at the expense of a lot of the other missions of NASA, one of which is the Science or the Space Technology Mission Directorate. And I have a letter from one of your former colleagues Bobby Braun, who is now a dean at the University of Colorado, in effect criticizing that—the loss of that directorate. And for the record, I'd like to introduce this letter, Mr. Chairman.

Chairman BABIN. Without objection.

[The information appears in Appendix II]

Mr. PERLMUTTER. So my question to you, sir, is—and some of the other questions that Mr. Brooks asked, the Chairman asked, Dr.

Bera, it seems to me that in this process of focusing on the Moon with a hope to get to Mars that we're losing a lot of the other science elements and a lot of the other Earth science programs at the expense of this exploration effort. Is that true?

Mr. LIGHTFOOT. I don't believe it is. In fact, I would argue that our technology budget—and when you look at it today, the exploration research and technology budget that we've proposed is \$1 billion. Today, the space technology budget is roughly \$700 million. So what we've done is we've aligned that technology budget with the exploration initiatives, and that particular part of the budget will now focus on what we call our long poles to getting to Mars, things like in-space propulsion, radiation safety, advanced life support that we need to actually take crews to Mars, and our entry, descent and landing activities that we're doing at Mars that we don't have to worry about at the Moon.

So I think we are—we still have a very balanced portfolio going forward, and I just think the alignment and the focus from an exploration standpoint is what you're seeing out of this budget.

Mr. PERLMUTTER. Do you think you're putting the building blocks in place to get our astronauts to Mars by 2033?

Mr. LIGHTFOOT. We're putting the building blocks in place. I don't know if we're going to get to it in 2033 or not, but we're putting the building blocks in place that we need with the systems we're putting around the Moon and on the Moon.

Mr. PERLMUTTER. I heard you say—and I think this was your—a quote—“We're going to try to get to Mars in the '30s,” try. Another one of my movies, in *Star Wars*—

Mr. LIGHTFOOT. *Star Wars*.

Mr. PERLMUTTER. —Yoda said, “Do or do not—

Mr. LIGHTFOOT. “There is no try.”

Mr. PERLMUTTER. —there is no try.”

Mr. LIGHTFOOT. Absolutely. I know it well.

Mr. PERLMUTTER. Okay.

Mr. LIGHTFOOT. I use it with my team all the time.

Mr. PERLMUTTER. All right. So, you know, I think that this Committee has been—you know, in Congress it's pretty fractious sometimes, but this Committee has been pretty solid in wanting to support the mission—the overall mission of NASA exploration, science, Earth science, deep space, and I think this Committee will be behind NASA in getting this done.

Part of me feels like a lot of this budget was written by the Office of Management and Budget, which I'm not happy about. So I want you to know that support that I think you have among all of us Democrats and Republicans. And I want to thank you again for your service, sir.

Mr. LIGHTFOOT. Thank you, sir.

Chairman BABIN. Thank you, Mr. Perlmutter.

I'd like to recognize the gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman.

And this is one of those rare occasions—well, actually, it's not. We agree—my friend from Colorado just expressed a concern about the Space Technology Mission Directorate, and I, too, am concerned about that, and I join him in expressing that. I have a letter as

well for the record that I would submit for the record today, and I hope you would pay attention to that.

[The information appears in Appendix II]

Mr. ROHRABACHER. And for the sake of our high school students there, yes, my friend from Colorado and I agree on this. We're working on it. That's the type of bipartisanship that this Committee is known for and the American space program is known for.

However, let me note that we have today—and this is for the kids—we don't have a full-time Administrator of NASA. This is a temporary Administrator here. This is not, however, a product of partisanship. This is not political. He's been in for a year. We have a good candidate, a great candidate, but yet we have to face this job with someone who's in the job temporarily.

This is a product of a couple of Senators who are bullheaded and a couple of Senators who are basically watching out for their own little domain rather than what's good overall for the country. And let me just put that on record so the kids recognize that is not politics. It could happen in any—this is not a political party-based outcome. It's based on the fact that there's several people over in the Senate that have demonstrated an arrogance that is unacceptable and makes things not work as well in Washington, D.C.

Let me now note now that we've talked a little bit about some of the other things, I, as you know, over the years—and when we're talking about kids—there's a big threat to these kids. There's a big threat to the people of the world, and it's the one thing that we seem to be ignoring, and I don't think that we're paying enough attention to it in this budget and others, and that is at any time there could be an asteroid or a near-Earth object that could come and wipe out half the world if not the entire planet. Their generation needs to know that we are preparing now for some way to defend this Earth, global defense, if indeed something is determined, is actually sighted ten years out—and we can do that—so that we could change the actual trajectory of an object like this.

Now, that is not something that's likely to happen, but it could happen. And if it does happen, it'll mean your entire generation is wiped out. So for these kids and for the planet in general, shouldn't we be doing more of that? And, for example, NEOCam is something that is absolutely necessary to see if an object would be coming from the Sun. Is there any money in this budget for NEOCam?

Mr. LIGHTFOOT. Yes, for the—so for the total picture of planetary protection is what we call it. We have an office—Planetary Protection Office in the agency—

Mr. ROHRABACHER. Right.

Mr. LIGHTFOOT. —and what we do there is we've increased the budget to do more observations that we're required to do, but we've also funded a mission called DART, which is going to be a mission that goes out and potentially determines whether we can deflect an asteroid or not. And we continue the technology work on NEOCam. We do not have the NEOCam mission yet, but the technology associated with what would become a mission is—

Mr. ROHRABACHER. Well, this is vitally—this is something that's important even though the chances of a horrible occasion like this are small, but the consequences would be incredible, catastrophic.

In terms of your science, and budget, and the fact that there seems to be a limitation on Earth science that has been mentioned, let me just note that, today, we do have commercial companies that are capable of doing things they couldn't do 30 years ago, especially in the terms of remote-sensing and Earth observation. There's no reason in the world why, if a private company can do something to make a profit at it, that we should take our limited budget for NASA and spend it on something that could be done and made a profit on in the private sector. So I would think that that's one thing that we should facilitate companies to get in, make a profit at doing those things in observation and sensing that they can do and make a profit at.

Lastly, I'd like to bring up another major impediment, and I've got one second to do it. And it's debris. And again, one thing that we can do as a government is work together with other governments, I might add, and other countries that want to do things in space to help clear the debris that's limiting what we can accomplish in space. Is there—what do we have on space debris?

Mr. LIGHTFOOT. Yes, we continue to work on the technologies, and I think this is a topic we've brought up with Scott Pace, the Executive Secretary for the Space Council—

Mr. ROHRABACHER. Right.

Mr. LIGHTFOOT. —is to look at an integrated policy because we all have an interest in this across the government.

Mr. ROHRABACHER. Well, I hope so, and I would—let me just say that, again, if we can just give these young people a world in which their opportunities are present, but by not doing things about debris or a possible threat from an asteroid, we're doing a great disservice to the next generation. So thank you for doing your part.

Thank you, Mr. Chairman.

Chairman BABIN. Yes, sir. Thank you.

Mr. ROHRABACHER. We'll work together on that.

Chairman BABIN. I'd like to recognize the gentleman from Illinois, Mr. Foster.

Mr. FOSTER. Thank you, Mr. Chairman—

Chairman BABIN. Yes, sir.

Mr. FOSTER. —and thank you for your service. I know it's—you know, it's tough.

I'd like to just start with one sort of big-picture item. Is it a correct reading of that plot that we looked at earlier that with a flat, flat budget, you don't get to the Moon and you certainly don't get to Mars? Is that correct?

Mr. LIGHTFOOT. I think it would be quite a challenge with a flat budget to do that.

Mr. FOSTER. Right. And that's true both for a flat, flat budget and one that even inflation-adjusted, flat including inflation?

Mr. LIGHTFOOT. Yes, we think that—we actually think the—including inflation we can do this. We've done the models. We've run the numbers to say if—

Mr. FOSTER. And that assumes shutting down the ISS at some appropriate time.

Mr. LIGHTFOOT. Absolutely.

Mr. FOSTER. But without shutting down the ISS, it's a non-starter?

Mr. LIGHTFOOT. Again, it depends on when we shut it down because it—that study showed '24 and '28. I mean, there's options in there in the middle if that makes sense. I mean, there's other times we can do it.

Mr. FOSTER. Yes, you can shut it down when you decide to.

Mr. LIGHTFOOT. Right.

Mr. FOSTER. But you need that money to even return to the Moon?

Mr. LIGHTFOOT. I believe so, to build the entire system to do that, absolutely.

Mr. FOSTER. Yes. Okay. And then I want to talk about—

Mr. LIGHTFOOT. That's why we have the plan we have, right? It's what we're showing to get off of it in 2024.

Mr. FOSTER. Now, if you talk about missions to Mars, an obvious suggestion is to have international partners taking a significant fraction of that. There's a lot and growing enthusiasm among other countries. And what is your attitude towards collaboration for a Mars mission with other countries?

Mr. LIGHTFOOT. Yes, we—all of this we're trying to do we think is going to be a great opportunity not only for industry partners in the country but also international partners. Last week, I was in Japan at the International Space Exploration Forum, and I was able to brief all our international partners that work with us on space station on what we're trying to do. They're all very interested in coming forward to help us not only at the Moon but also as we go to Mars. That's our plan all along is to include that. That's one of the differences between the '60s and now is we have other players that want to come and be part of this. They just need us to lead.

Mr. FOSTER. And the other thing that is potentially really changing are the increased capabilities of artificial intelligence and robotics, that you have robots today doing things that could only be done by people even a few years ago. And so this is an opportunity to really knock some cost out of future missions by either having robots precede people to—which is—it seems like there is a shift in focus in that direction now, where you're talking about relatively sophisticated robotic-first missions and then deferring the human—the much more expensive manned component as necessary to meet your budgetary constraints.

Mr. LIGHTFOOT. Yes, we're using robotics—to your point, we're using robotics on the International Space Station actually doing things robotically that ten years ago we needed crew time for. We will take things—when SpaceX flies to the station today, for instance, they carry instruments in the trunk, in the unpressurized cargo area for the SpaceX. While the crew's asleep, we take the arm, we would pull it out, we do it all robotically from the ground. You can do the same thing from the platform at the Moon. You can do robotic operations of landers on the Moon, so it goes both ways.

Mr. FOSTER. Sure. You can have—you know, the old dream—

Mr. LIGHTFOOT. The advances are incredible.

Mr. FOSTER. Yes, the old dream of having self-replicating factories on the Moon using completely robotic equipment, these sort of things people are making, you know, prototypes of components of that on Earth, and it's something actually the next generation

should get very excited about because these sort of prototype facilities on Earth could really lead the way for, you know, orders-of-magnitude reduction in the cost of future missions.

Mr. LIGHTFOOT. Yes, we believe our International Space Station lets us demonstrate that in space as well.

Mr. FOSTER. Okay. Now, in my last time, I'd like to go to something very microscopically focused, which is the choice of using high-enriched uranium or low-enriched uranium for power sources. There is a huge difference in the danger, the proliferation danger and the terrorist danger, between high-enriched uranium and low-enriched uranium. If you have weapons-grade high-enriched uranium and a terrorist steals it, they can, without much sophistication, make a nuclear weapon. On the other hand, if they steal low-enriched uranium, they have to go and build a centrifuge hall and so on, and so it's almost useless to them.

And so, I'm a little puzzled why you seem to have both high-enriched uranium and low-enriched uranium for propulsion and for surface power in different parts of your program. And I was wondering specifically, have you looked at the real cost of security when you choose high-enriched uranium for—that means you need armed guards, you need barbed wire, you need everything, and it's very expensive because of the terrorist threat if you choose high-enriched uranium. You know, it does make a slightly more compact design for typical reactor applications, but I'd encourage you to look hard at seeing if you can lead the world in standardizing low-enriched uranium.

Mr. LIGHTFOOT. Yes, we've been working on technologies for that for the exact reason you're talking about. It is high-enriched uranium creates a lot of extra challenges there. We've been looking at it for power and propulsion. What I'd like to do is let our team bring you—get—provide you a report on what we've been doing in LEU and how we're trying to use it and the applications we see going forward. Would that be okay?

Mr. FOSTER. Yes, it'd be very—yes, I mean, there was a letter from a long list of Nobel Prize winners just focusing on how the United States should lead—there's a danger also that countries which are not necessarily nuclear countries will say we need a large inventory of high-enriched uranium not to build bombs but for their space program. And so if there's a technological way to avoid this, I just really encourage you to try to lead the world towards exclusively using non-weapons-grade uranium for your programs.

Chairman BABIN. Okay. Thank you. The gentleman's time is expired.

And I'd like to recognize the gentleman from Oklahoma, Mr. Lucas.

Mr. LUCAS. Thank you, Mr. Chairman. And it is always a challenge on the Republican side to follow Mr. Rohrabacher from California, but here we go.

A number of my colleagues have touched on this question, Acting Director, about the nature of the agency and the ability of the things to be done that are necessary in this environment we work in with an Acting Director. And you're a long-term career guy, and you've done an outstanding job and a very good role as Acting Di-

rector. But ultimately, as my friends are noting here, in the environment we work in, the resources that the agency needs in the long-term, having a Director nominated and confirmed by the United States Senate from the Administration is critically important, and I think we would all agree on that. And while this body can't really give advice to that other institution—notice I was very careful in my phraseology there—nonetheless, having a full-time Director is a critically important thing.

And I spent five or six years sitting next to the OMB Director on the subcommittee of another committee, and I understand how challenging the circumstances can be there, so we need someone, and I agree with my colleagues.

Another observation in a general sense I would note my friend from Colorado's focus on having people on Mars by 2033, that would make me 73 years old. I would like to be alive for this great accomplishment. And while I come from reasonably decent genetics, once we get past the mid-80s, it starts to be a little questionable, so I want to help you get there and the agency get there.

So for a comment or two in the weeds now that we've discussed indirectly Mr. Mulvaney and the environment we're working in, NASA's expressed an interest in building a second mobile launch platform for the SLS as a way to address some of the scheduling pressure on the first crewed mission of SLS and Orion. And I was looking through your request, and I noticed the second platform is not included. What effect would building a second mobile launch platform rather than modifying existing platform have on the launch schedule for SLS and Orion, and what would the cost be thinking about our justifications to our other friends in government about why we need the resources to do things?

Mr. LIGHTFOOT. Yes, I think we took a hard look at that during this cycle, and what the advantage of the second mobile launch platform gives you is I could fly on the mobile launch platform I'm building today, and I could potentially fly Orion if I bought another interim cryogenic propulsion stage, an upper stage. So I could fly quicker, fly humans quicker, probably 2022 time frame.

The opposite of that is the cost is a pretty expensive proposition to build a new mobile launcher and to buy another interim cryogenic propulsion stage. And so just as we had the discussion, we had the debate, and our answer came back we just should stick with our plan that we've got. So, I mean, that was the difference. We can provide you the numbers. I'd be glad to provide the cost associated with that to the Committee.

Mr. LUCAS. I would be fascinated by the numbers, Director—

Mr. LIGHTFOOT. Okay.

Mr. LUCAS. —because that's one of the issues that we as a committee need to take up in our work with the appropriators if we really want to get there in 2033 or a day or two earlier, providing those necessary resources.

Now, let's touch for a moment, are the flat, notional, nominal, topline, out-year numbers on the budget request a result of the decision to keep funding flat, or are they simply placeholders for subsequent requests that the Administration will be making as the long-term formula gets put together as all the pieces come into place in the Administration?

Mr. LIGHTFOOT. Yes, we believe that our job is to present the budget we need every year to OMB, and so without years being notional, I don't really think about them either way as placeholders or direction. I just think we have to present our budget going forward, so—

Mr. LUCAS. Another observation that I would make to my colleagues on the committee that it's our responsibility to address some of these long-term issues, our responsibility to focus the resources to do what is in the common good and the best interest.

Just one casual question to conclude with, Director. Tell us about the funding situations and circumstances of the James Webb. Are we still on track? Do we still have the resources necessary to help it live up to its potential?

Mr. LIGHTFOOT. Yes, we believe we have the resources necessary now. We're in a pretty significant review from a schedule standpoint about when we'll launch it. We're having some challenges with a couple of the technical parts of the spacecraft, not the telescope part but the actual spacecraft bus that's being built. The telescope is already delivered and it's ready to go. We've done through—gone through the testing. They're around the sunshield and around some of the propulsion elements associated with that. So we—we're—I'm supposed to get briefed by the end of the month on where we are, and we'll let—obviously let everybody know where we are from that standpoint.

Mr. LUCAS. And I bring that up, as important as the manned program is, nonetheless, your satellites in orbit around the Earth have provided us with, as my mother would have said, a lot of "Buck Rogers" moments in the last 20 years, and we need to continue that focus and generating the imagination of our fellow citizens.

With that, I yield back, Mr. Chairman.

Chairman BABIN. Yes, sir. Thank you very much, Mr. Lucas.

And I'd like to recognize the gentleman from Florida, Mr. Crist.

Mr. CRIST. Great. Thank you, Mr. Chairman.

Chairman BABIN. Certainly.

Mr. CRIST. I appreciate that.

And thank you, Mr. Lightfoot, for being with us today. We appreciate the situation you're in, and thank you for your tenacity in the mission.

And you may have addressed these things. I had to step out for a meeting or two. During your state of NASA address last month, you mentioned that the Administration is putting NASA, quote, "on a path to return to the Moon with an eye towards Mars." That's an interestingly worded statement, and I appreciate that. It seems to avoid a firm commitment as to either of the two objectives may be accomplished. And while it's clear that this fiscal year 2019 budget focuses heavily on lunar exploration, I am a bit concerned that the Administration may be shying away from Mars. Can you elaborate on that? And you may have already, so forgive me—

Mr. LIGHTFOOT. Yes.

Mr. CRIST. —if that's the case.

Mr. LIGHTFOOT. No, it's fine. I'd be glad to articulate where I think we are. I think we are still keeping an eye on Mars for sure, and the technologies I mentioned earlier around—that we're going

to still continue to fund. There are some pretty long—what we call long poles, challenges, to get to Mars: entry, descent, and landing; and space propulsion; advanced life support; radiation protection for the crews as we go there. These are big challenges for us. So we're going to keep working on those while we build the systems that we're building at the Moon that we think are going to be extensible to get us to Mars.

The Gateway is a critical piece of that. If—we could've decided just go to the Moon from Earth, right, and then that would've not been extensible to do anything to get to Mars, but the fact that we're going to build a platform that allows us to operate to and from the platform to the Moon can also be the platform we use to operate to and from to Mars. So that's—I think that's a pretty nuanced difference from a technical perspective in terms of this architecture.

Mr. CRIST. Where do we think we are in terms of the timing of a Mars mission?

Mr. LIGHTFOOT. Well, you know, as Congressman Perlmutter said, he wants 2033. I think what we'll do is see what—how much progress we make in the lunar vicinity in building those systems we need and knocking down the technical requirements, but it will be no earlier than 2033, how about that? I'll just leave it at that.

Mr. CRIST. Okay. I appreciate that. Is there an opportunity, do you think, for the private sector to assist NASA in getting humans to Mars?

Mr. LIGHTFOOT. Absolutely. We—there—not only an opportunity, we are expecting them to help. I mean, they're helping today by helping us with low-Earth orbit the activity we're doing from a cargo perspective and ultimately the crew perspective and even some of the systems that we have on the International Space Station. We want to leverage that in a big way as we move forward because the more they can do, the more I can move out going forward. So it's the entire system of what we're doing in low-Earth orbit, around the Moon, and getting to Mars. That's going to need international cooperation, it's going to need American industry and commercial folks to come forward, and then the NASA team themselves. And I think that's what's important is to look at that total spectrum.

Mr. CRIST. Yes, sir. Thank you. The budget proposes to end direct funding for the International Space Station in 2025 when under this proposal the station would be transferred to commercial management and control. Will the research being done on the space station to mitigate the risk of extended space travel on humans be completed by 2025?

Mr. LIGHTFOOT. Well, we have a roadmap for doing that research obviously. The important thing is we're not going to quit doing research. We'll be doing research around the Moon on the reaction—what happens to humans as well. That's part of our discussion this upcoming year is what do we need to do and what commercial platforms can actually provide us the same research that we get on the International Space Station. So we will get the research done that we need to do to move humans forward, but we don't ever stop researching for humans no matter where we are, at the Moon or even at Mars.

Mr. CRIST. Great. Thank you very much, Mr. Lightfoot. I'll yield. Thank you, Mr. Chairman.

Chairman BABIN. Yes, sir. Thank you.

I'd like to recognize the gentleman from Florida, Dr. Dunn.

Mr. DUNN. Thank you very much, Dr. Babin—

Chairman BABIN. Yes, sir.

Mr. DUNN. —Mr. Chairman. I'm going to stay on the same line of questioning if I may and ask you to elaborate a little more about the transfer of the space station to the commercial sector, private sector. You know, how exactly does that work?

Mr. LIGHTFOOT. Well, part of it is—so we have to coordinate with our international partners, too, I want to be really clear, as they are part of the International Space Station today. What we're really looking for is—

Mr. DUNN. Are all the governments stepping out or just ours? It's just ours?

Mr. LIGHTFOOT. Yes, we've just proposed it, and we've been talking to them going forward—

Mr. DUNN. Okay.

Mr. LIGHTFOOT. —but today, all the governments were agreed to to 2024. If we go past 2024, all the governments are going to have to agree to as well.

Mr. DUNN. So a new negotiation?

Mr. LIGHTFOOT. Yes. And I think that's not a difficult thing. It may be difficult for them and their ministries and all the different things they do.

But what's really important here is we think when you look at the rise of the commercial entities and the—really the—their abilities and the things they're bringing where there's the habitats—we got a tremendous amount of interest in our NEXTSTEP, BAA, the Broad Area Announcement around habitats. We think by 2025 there's great potential for them to have orbiting platforms in low-Earth orbit. It doesn't have—some of them might want to use the International Space Station; some may want to stand alone. So the plan would be those come along, and if they do, we can get our research done and use them—just basically buy that as a service for our needs going forward. So this next year we'll get—we'll ask folks for that kind of feedback. We'll get that kind of feedback from all these companies, and we'll see where they really are, which allows us to influence our 2020 submit based on that—what that date might be.

Mr. DUNN. So during—on the same theme of reorganization here—you stated that NASA plans to reorganize the Human Exploration Operations Missions Directorate and Space Technology Mission Directorate. Can you also elaborate on that transition?

Mr. LIGHTFOOT. Yes, so the goal here is to move what the Space Technology—Space Technology Mission Directorate today into an exploration, research, and technology arm, and we're still working the details around the organization. We'll have that back in the spring. And what we're really trying to do is make sure our technologies that we're working on are truly aligned with the things we're trying to do at the Moon and ultimately at Mars, as I talked about some of the technologies we got to work on before.

And we think having them housed under one organization, while today I am very comfortable—I really am pretty comfortable with the alignment, there's things we're doing in technology that may not be aligned. You know, there's other things, and so we're trying to make sure they're all focused. And having them under one spectrum so I know what I'm doing in low-Earth orbit, I know what I'm doing with the Moon, and I know what I'm doing with my technologies, I can make sure those are integrated and not on their own, so that's what we're trying to do.

Mr. DUNN. I'm going to lower our altitude just a little bit here. I'd like you to elaborate on the X-Plane program, which is fascinating to me. And by the X-Plane, I think you mean the low boom.

Mr. LIGHTFOOT. Yes.

Mr. DUNN. Are there other X-Planes you're working on?

Mr. LIGHTFOOT. Yes, we have a plan ultimately I think for four X-Planes in our—in what we call our New Aviation Horizons. The first is the low boom supersonic demonstrator—flight demonstrator.

Mr. DUNN. Do you feel pretty confident about that?

Mr. LIGHTFOOT. Absolutely.

Mr. DUNN. Great.

Mr. LIGHTFOOT. I feel very confident. I think you'll see some announcements probably in the next month about some selections we've made moving forward.

Mr. DUNN. I'm going to hold you to that.

Mr. LIGHTFOOT. You can on that one. We're pretty excited about that. And the goal there of course obviously is to create supersonic transport across the continent of the United States, which we can't do today, right? Can we provide a demonstrator that allows the commercial market to learn from that configuration and move forward?

The next demonstrator, the next X-Plane is what we call X-57 Maxwell. It's an all-electric aircraft—

Mr. DUNN. Yes, yes.

Mr. LIGHTFOOT. —and so that's the next one. And they we're going—we're continuing working on subsonic technologies, which is flight technologies from a subsonic perspective. That would be the next demonstrator. It's not in this budget, but that would be the next one. There'd be a third one even. And we just think—I mean, I just think it's critical that we stay engaged from an aviation and aeronautics technology perspective.

Mr. DUNN. It is.

Mr. LIGHTFOOT. It's a huge global market that we don't want to get out of.

Mr. DUNN. Yes, no really, I'm glad that NASA hasn't lost sight of the atmospheric efforts.

Mr. LIGHTFOOT. Not at all.

Mr. DUNN. That's very good. Thank you very much, Mr. Chairman. I yield back.

I appreciate your answers, Mr. Lightfoot.

Chairman BABIN. Yes, sir. Thank you.

I'd like to recognize the gentleman from Virginia, Mr. Beyer.

Mr. BEYER. Thank you, Mr. Chairman, very much.

Mr. Lightfoot, thank you very much for being here. In your testimony you mentioned that the budget request provides for, quote, “critical infrastructure indispensable to the Nation’s access and use of space,” and you discuss the importance of maintaining the ISS and supplying both crew and cargo through NASA’s commercial cargo partners. I certainly agree that those are very important priorities, which is why I want to discuss the Wallops Flight Facility in Virginia. The space launch range at Wallops is technically NASA’s only launch range, considering that launches from Kennedy Space Center in Florida use the Air Force’s eastern range. In fiscal year 2018, the National Defense Authorization Act that Congress established a launch support and infrastructure modernization program for DOD’s eastern range in Florida and the western range in California. I’m concerned because there appears to be no similar program within NASA to sustain and invest in long-range assets for Wallops, which are also used for your mobile range missions in the United States and around the world.

Even more troubling, the fiscal year 2019 President’s budget request did not include any funding for the 21st-Century Launch Complex Program, which has been used to fund some of these needs at Wallops in the absence of a dedicated launch range program. This Committee included its support for the continuation of the 21st-Century Launch Complex Program in the 2017 NASA Transition Act, but I’m disappointed the budget request didn’t follow along with this Committee’s recommendations.

So I was encouraged that Chairman Culberson, Ranking Member Serrano, and Members of the House Appropriations’ Subcommittee on Commerce, Justice, Science, and Related Agencies continued funding for this program in their fiscal year 2018 bill, and I know that my colleagues and I will be pushing for this again in our eventual fiscal year Appropriations Act.

So my question is how is NASA investing in upgrades at Wallops to improve the launch range infrastructure, and why are there no dedicated range improvement programs for NASA’s range as there are for the DOD ranges?

Mr. LIGHTFOOT. Yes, so the way we—what we typically do from an infrastructure standpoint is we’ll build the infrastructure, and then once the program comes into operate it, they inherit the infrastructure costs. So we’ll do—kind of do the upfront investment, and then we let the programs like commercial cargo that flies out of Wallops, as you know, Sounding Rockets Programs, the Balloons Programs, they support the infrastructure that’s there. So that’s where we are.

What I will do is I will—I don’t know the exact details of what we’re funding there from an infrastructure perspective, but we have an infrastructure process through our Office of Strategic Infrastructure that allows us to look for modernization and investment. And what I’ll do, sir, is I’ll just provide you what we’re doing at Wallops inside that budget.

Mr. BEYER. Okay. That’d be great because the companion question is, though, wouldn’t the continuation of the 21st-Century Launch Complex funding help address some of the backlog, continue to make NASA’s range more competitive, basically just strengthen NASA’s only range at Wallops?

Mr. LIGHTFOOT. Yes, I think—well, obviously, it would, but we fund that out of our Safety, Security, and Mission Support area, which is our—kind of our institutional area, and that's an area that gets challenged quite often, so that's—let us get you the data on where we are. I'd rather not try to just do it off the top of my head from that standpoint.

Mr. BEYER. Okay. Great. Mr. Chair, that's all I have, so I yield back.

Chairman BABIN. Yes, sir. Thank you.

And now I'd like to recognize the gentleman from Indiana, Mr. Banks.

Mr. BANKS. Thank you, Mr. Chairman. And thank you, Mr. Lightfoot, for being here. You have been an adequate Acting Administrator. You've done a great job. We appreciate your leadership, so no offense to you, but I hope next time we're sitting here that Administrator Bridenstine will be in the chair. It's an embarrassment to the process that that hasn't happened yet, but we appreciate the leadership that you have provided in the meantime.

I want to ask you a little bit about the WFIRST mission. This project was a top priority for astronomers in the last decadal survey. What would be the consequence of canceling the mission in your opinion?

Mr. LIGHTFOOT. Yes, I think the big consequence is the gap in astrophysics data that we would get from the WFIRST. I mean as—to the astrophysics community, that's a challenge from a scientific perspective.

The other—the positive side of that, though, is that we can—that those funds can perhaps get the data in a different way, and I think that's what our Science Mission Directorate is going to look at.

Mr. BANKS. So you would agree that it would undermine the decadal survey?

Mr. LIGHTFOOT. It's definitely what the decadal survey has asked for, but we think there's other ways to get that same data.

Mr. BANKS. You do? Okay. Well, many of the important parts of the spacecraft for the WFIRST mission have already been completed. Would you agree?

Mr. LIGHTFOOT. I'm not sure I would agree.

Mr. BANKS. For example, at the Harris Corporation, which is a major employer in my district, several hundred constituents of mine have completed construction of the optical assembly. So how much of this spacecraft for the mission has already been completed?

Mr. LIGHTFOOT. Can I get you those numbers? Can I just provide them for the record? Because I don't—again, I don't want to do it off the top of my head, but there's—

Mr. BANKS. Yes.

Mr. LIGHTFOOT. —there's quite a bit more to go.

Mr. BANKS. Okay. Please do. Thank you very much.

Can we really expect, though, substantial savings given the amount of work, do you believe, that has already gone into the WFIRST mission?

Mr. LIGHTFOOT. I think when you see the numbers—when you're looking at a \$3.2–3.9 billion mission, we have not spent nearly that much at this point.

Mr. BANKS. Okay. Thank you. I look forward to seeing those figures.

I know the Webb Space Telescope has already been mentioned. It continues to experience several complications on the path to being ready to fly. Given the intricacy of the design with no room for error in the deployment, how would NASA's ability to conduct deep space science if WFIRST was canceled and if there were further problems with the Webb Telescope after it was launched?

Mr. LIGHTFOOT. I think that's the balance and the challenge that we're counting on. We're counting on tests in James Webb to fill the astrophysics needs for quite a bit of time, so clearly, if we had challenge with James Webb, that would be something we'd have to look at.

Mr. BANKS. Okay. And finally, in this day of ever-changing innovation and technological advancements, could you explain the reasoning for merging the Space Technology Mission Directorate with an operations organization?

Mr. LIGHTFOOT. Yes, I think when you look at the way—there's really three lines of business in here. There's the low-Earth orbit activity where the International Space Station is; there's the lunar vicinity area, what we're going to do at the surface of the Moon and around the Moon; and then there's deeper space exploration, which includes Mars. If you're going to have a steppingstone approach, those three steppingstones need to kind of be aligned together, and so that's what we're trying to do. And if you look at the total budget, it's actually a better budget for technology than we had, a standalone Mission Directorate, and it'll be more aligned and more focused, we believe, with what we're trying to do.

Mr. BANKS. Okay. Thank you very much. That's all I got. I yield back.

Chairman BABIN. Yes, sir. Thank you.

I'd like to recognize the gentleman from California, Mr. Knight.

Mr. KNIGHT. Mr. Lightfoot, thank you. Thank you for your leadership, and thank you for hiring my Legislative Director and taking him away for me. I'm sure he's doing as good a job for you as he did for me.

You know what we're going to talk about. We're going to talk about the big A. So the LBFD, the UEST, these are kind of projects that I think would advance mankind. It would definitely advance this country, and I'm going to jump on an airplane tomorrow and I'm going to .7 Mach, hopefully, if the winds aren't so bad. But if I jumped on an airplane in 1968, I'd be going .7 Mach across this country. And so for about 62 years, it's been that. Coming East, we get to go a little faster; going West, we get to go a little slower, but that's about where we are.

And so I think the LBFD and then even transitioning a little bit into ultra-efficient subsonic transport and saving fuel costs and putting these same amount of people into the airplane but saving those fuel costs, maybe making a little wider seats for me, too, would be a big, big deal to advancing mankind and taking that step

that maybe we haven't taken in the last 60-some years. So that's just my pitch to continue to push on that.

New horizons—and this is a big part of that—but all of the X-Planes—and I think that Dr. Dunn started on what you're doing with the X-57, and I know that that's progressing very well and what we're doing with the Low-Boom Flight Demonstrator. What else are we seeing in the future outside of what I've kind of just stated?

Mr. LIGHTFOOT. Yes, there's a couple of things that we're working on in aeronautics that are just as important in my opinion and that's getting—integrating unmanned systems into the airspace. Our teams at Ames are working really hard on that—well, all over the country frankly are working on that with our partners at FAA and how we would go about doing that. You can see the proliferation that's happening everywhere. There's personal air mobility coming along, and we're involved in the technology and research around that.

Hypersonics, we're involved in that from a—

Mr. KNIGHT. That's next.

Mr. LIGHTFOOT. —very much a research perspective, so those are all in that budget that go with the X-Planes that you talked about, and very important to us and—I think.

Mr. KNIGHT. So hypersonics over the last five or ten years there's been a lot of advancements to get us to probably a position where hypersonics are very achievable, very reachable. NASA's been a big part of that, and industry has been a big part of that. I think that we're going to see that not just from what NASA can do with hypersonics but from a national defense situation, hypersonics are very, very important in moving forward with new technologies, new ceramics, and new materials that make those things achievable.

I'm going to push over into another realm. We've got some companies out there that are doing some innovative things, and one of them is in Mojave. It's a Paul Allen company called Stratolaunch. Stratolaunch is going to fly an airplane this year, a very large airplane, and when they do that, they're going to kind of bring a new realm into what we can do for space launch because that airplane will be able to fly at a couple different airports depending on the taxiways, and they'll be able to launch differently than just on the West Coast and just on the East Coast, is what we hope. Do you see a good partnership with companies like that with Stratolaunch and things like that?

Mr. LIGHTFOOT. Yes, I think we have that we have—our launch services process that we have inside the agency and flight opportunities process we have inside the agency really allows new entrants to come in. We have a really good on-ramping way for them to demonstrate their capability and become part of our—really our toolbox to get our missions done, so yes, absolutely we see an opportunity for those folks.

Mr. KNIGHT. Yes, I think that's a perfect answer, that this could be part of the toolbox. This is part of the future.

And then closer to home to me that not many people know about but everybody's talked about the James Webb Space Telescope, and so you know I'm going to talk about SOFIA, all of the things that SOFIA does. How is that doing?

Mr. LIGHTFOOT. Still continues to fly its missions. We constantly—not only do—are we flying missions, we’re engaging a lot of educators in that process as we go forward. The data is coming back. It’ll go through senior review in a couple years just like all our missions do, and we’ll see—it’ll get a good assessment of the science value versus the cost and that’s what we’ll do so—

Mr. KNIGHT. Yes.

Mr. LIGHTFOOT. It’s in—it’s still over in Germany right now, and there’s annual maintenance period—

Mr. KNIGHT. Correct.

Mr. LIGHTFOOT. —so we look forward to getting it back here in a couple—I think we get it back in a couple of weeks.

Mr. KNIGHT. Yes. Thank you very much, and I yield back.

Chairman BABIN. Thank you very much. And, yes, we’ll take a second round here. And I’ll tell you what, I’ll call on you first there, Mr. Bera, the gentleman from California.

Mr. BERA. Great. Thank you, Mr. Chairman. I’ve just got a quick question, and again, I appreciate the service, Acting Administrator.

You know, when you talked about the space technology budget increasing from \$700 million to \$1 billion, we’re happy about that obviously. I think, you know, echoing a theme that I think a number of members have said and I certainly touched on—one of the concerns, though, is with that increased budget but with that increased focus on exploration we do have a worry that more of the budget for space technology is going to focus on the exploration mission as opposed to kind of the cross-sectional multi-mission piece. And again, it’s that borrowing from Peter to pay Paul. Could you touch on that?

Mr. LIGHTFOOT. Yes, I think that’s a concern of mine as well. I mean, we worry about that in the agency all the time in terms—there’s several things, right? There’s the concern of will the technology get eaten by the operational side of the house, right?

Mr. BERA. Right.

Mr. LIGHTFOOT. And I think that’s the biggest concern we had for a while. What we’ve done, though, is we’ve put some things in place that allow us to monitor that and make sure we’re not doing that. I have a strategic integration activity between the mission directorates today that allows—they have to come to me to say when they’re doing that, so we don’t internally rob from Peter to pay Paul, and I’m pretty comfortable with that process and feel like that alignment will stay in place.

Not only that, when you see the details behind the engineering—or the exploration research and technology line, there’s still some crosscutting budget in there. There’s—just the majority of it is going to be focused to exploration. There’s early-stage activity still there, a small amount but it’s still in there to make sure we’re keeping that seed corn, not just all exploration-focused but most of it is.

Mr. BERA. And, you know, as my colleague from Colorado, Mr. Perlmutter, pointed out I think most of the Members on this Committee in a bipartisan way are very supportive of the multi-mission aspect of NASA and—as it’s our constitutional duty to set budget numbers and so forth. We do want to work with NASA and work

with your administrators to make sure we're robustly supporting that multi-mission focus.

I do have one last question. Would you agree that the decadal survey has served us fairly well in terms of prioritization and so forth?

Mr. LIGHTFOOT. Oh, yes. I think it's a stalwart for what we do from an agency standpoint—

Mr. BERA. Right.

Mr. LIGHTFOOT. —but we don't always do exactly what the decadal says. It's just a good advising for us.

Mr. BERA. And that's a somewhat objective, nonpolitical way of advising and prioritizing projects. Well, I'll just go on the record. Not doing the WFIRST mission from an astrophysics perspective is probably going to be perceived as leaving a hole in that continued science. I think we ought to work together to try to figure out how we continue to fill that hole or continue to move forward with the WFIRST project.

Thanks. And I'll yield back.

Chairman BABIN. Okay. All right. Thank you.

And I have a few more questions, too, if you don't mind. Concerning Orion, last year, NASA requested \$1.186 billion for Orion, and Congress appropriated \$1.35 billion in fiscal year 2017, which continues under the current continuing resolution. The additional funding was necessary to carry out important work on EM-1 rather than deferring it to EM-2. NASA is once again requesting to decrease Orion funding. What content would be removed if NASA received \$1.16 billion rather than the \$1.35 billion in fiscal year 2019?

Mr. LIGHTFOOT. Let me—can I submit that for the record?

Chairman BABIN. You sure can.

Mr. LIGHTFOOT. Let me get that back to you so I get the exact content that's in there.

Chairman BABIN. Yes, we'd like to know.

Mr. LIGHTFOOT. Yes.

Chairman BABIN. Okay. And then concerning risk, in your January talk to CSIS, you spoke about risk and that trading between specific engineering choices and national strategic imperatives is a difficult but occasionally necessary discussion. Is this the right time now for the Nation to reassess how we handle risk? Is this something that NASA should engage with industry, trade associations, and academia on?

Mr. LIGHTFOOT. I think this is a good time as any to do that. I think we should do that all the time. You know, nothing we're going to take on in this exploration agenda is going to be without risk.

Chairman BABIN. Right.

Mr. LIGHTFOOT. But we're not going to do it in a way—you know, we're not going to take excessive risk either. We're going to make sure we manage that risk appropriately. And I think the American public, this body, all need to understand that that's what that risk is. And risk comes in many fashions. As you know, Mr. Chairman, there's technical risk for a given mission, there's political risk for not doing it or doing it, there's programmatic risk in terms of the budget and the challenges we're trying to meet. And at the end of

the day, I could make an argument that the least risky thing is to sit on the ground and not fly.

Chairman BABIN. Right.

Mr. LIGHTFOOT. But I could tell you that's probably the most risky thing for us to do as a nation from an overall perspective.

Chairman BABIN. I would agree.

Mr. LIGHTFOOT. And so that's—to me is—so I think the time to have that discussion is probably now as we enter this next phase of exploration and pushing and then would love to engage not only the groups you talked about but frankly this body as well because you guys are the ones that help us authorize what we're going to go do and understand that.

Chairman BABIN. Okay. And then on hurricane relief, you know, we just got hit really hard by Hurricane Harvey at Johnson Space Center. My entire—all nine counties that I represent were federal declarations of disaster. What is the status of hurricane funding for NASA centers?

Mr. LIGHTFOOT. Yes, we're working the apportionments with OMB now—

Chairman BABIN. Yes.

Mr. LIGHTFOOT. —at a level of detail that we haven't done before, so we're trying to make sure we get that done correctly and so that we're all tracking where the dollars go and make sure we know where it is, so we're working that, and we should get that out hopefully soon.

Chairman BABIN. Okay. And then to kind of go back to a subject that's already been broached this morning on the mobile launch platform, you had spoken to it already, but I was wondering about the—I was down in Florida a couple weeks ago for the National Space Council meeting, and you were there and I appreciated your testimony. The Center Director was telling us about some of the things that he thought about the mobile launch platform, and it sure sounded like it would be a great thing if we could get a second one.

And as far as the time element and the construction of it, if I understood you correctly earlier today—you said that's really kind of off the table right now, correct?

Mr. LIGHTFOOT. Yes.

Chairman BABIN. If we decided to put it on the table, would we be behind the eight-ball as far as the time elements in EM-1 and EM-2 launches?

Mr. LIGHTFOOT. I think the challenge would be if we—if a mobile launcher showed up on the—as something we're going to go build, we would not start modifying the one that we're building for EM-1. We would not start that modification process, and therefore, once we flew once on that launch platform, it's now ready to fly again, and so we would go through the process of hopefully purchasing another ICPS—

Chairman BABIN. Right.

Mr. LIGHTFOOT. —again with the expense that comes with it. I want to be really clear.

Chairman BABIN. Yes.

Mr. LIGHTFOOT. And also human-rating that and so we could fly Orion with crew quicker. And so maybe the first launch off of the

new MLP that we would build in that mode would—might be EM-3 or EM-4, right, but it would leave us the capability to keep flying on the mobile launcher that we're building today instead of going in and modifying it.

Chairman BABIN. Well, modifications on the existing mobile launch platform, are they—does that lead to any kind of an increased risk to be changing and remodifying and remodeling, et cetera?

Mr. LIGHTFOOT. Yes, I think it's—we believe there is risk with that. I mean, we've got a 33-month time period right now between—

Chairman BABIN. Right.

Mr. LIGHTFOOT. —the EM-1 and EM-2, mainly to do those modifications because basically you have to add just a length to it—

Chairman BABIN. Right.

Mr. LIGHTFOOT. —to be able to handle the new—the Block 1B SLS configuration, so that—any time you do that, you're going to have some risk when you go in there, and that's a pretty complex piece of hardware. When you walk up and down the mobile launcher, you see how complex it is, so to add that—

Chairman BABIN. Right.

Mr. LIGHTFOOT. —is some risk, so I think there's risk there. There's also risk in the amount of dollars we need to go do an MLP and an ICPS, and that's got to be—you know, that's a—I would say that's above my pay grade to make that decision. But from an Administration perspective, we just decided that we'd rather not—that those dollars weren't really available for us to go do that.

Chairman BABIN. But ideally, it would be best to have a second one—

Mr. LIGHTFOOT. You could—

Chairman BABIN. —that you built from scratch?

Mr. LIGHTFOOT. You could see that from a—it depends on what your definition of ideal is, but yes.

Chairman BABIN. Got you. Okay. All right. Mr. Lightfoot, this concludes my line of questioning, unless anybody—I don't think there's anyone else here. But I want to just commend you, compliment you on an excellent job that you've done stepping into the gap as our interim Administrator.

And I would also like to echo some of the comments of my colleagues today that we're certainly hoping that the one that the President—Mr. Bridenstine that the President has chosen to be the next Administrator, we hope that that happens soon. But listen, that doesn't take anything away from the great job that you've done, and I just want to thank you and thank you for being here this morning as well.

Mr. LIGHTFOOT. All right. Thank you all. Thanks to the Committee.

Chairman BABIN. Okay. All right. I want to thank the witness and his valuable testimony, the Members for their questions. The record will remain open for two weeks for additional comments and written questions from Members.

So with that, this hearing is adjourned.

[Whereupon, at 11:35 a.m., the Subcommittee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Robert M. Lightfoot, Jr.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

“An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2019”

Mr. Robert M. Lightfoot, Jr., Acting Administrator, National Aeronautics and Space Administration (NASA)

Question submitted by Ranking Member Ami Bera, House Committee on Science, Space, and Technology

1. The FY 2019 proposal includes \$50 million a year over the budget horizon for planning a Mars Sample Return mission. The request also notes that the Sample Return mission may involve commercial and international partners. How would the total of \$250 million requested over the next five years for planning a Mars sample return mission be spent and how would commercial entities potentially be involved? Under the FY 2019 request, when could we expect to have scientific samples returned from Mars?

Answer: NASA intends to seek and engage interested partners from both commercial space and international space agencies in studying potential architectures for Mars Sample Return (MSR), and where there is credible interest, develop a plan for implementing MSR. The funding would be used to support these studies, peer reviews, and early technology investments where appropriate. We are assessing MSR mission launch dates as early as 2026, as well as later dates. If MSR were to be launched in 2026, the samples would be returned to Earth in 2029. If NASA were to launch the MSR mission in 2028, samples might be returned as early as 2031, but the timing of the Martian dust storm season or Martian winter could reduce fetch rover operations and likely delay return until 2034.

2. The budget request for FY 2019 proposes a new LEO Commercial Development Program funded at \$150 million per year for the five-year budget runout.
 - a. What specific objectives would this Program address?

Answer: The primary purpose of the Commercial low-Earth orbit (LEO) Development program is to spur a vibrant, sustained U.S.-led, commercial LEO human space flight marketplace where NASA is one of many customers. The vision includes one or more privately-owned/operated platforms – either human-tended or permanently-crewed – together with transportation capabilities for crew and cargo that enable a variety of activities in LEO, where those platforms and capabilities are sustained to a greater degree than today by commercial revenue. These future platforms may either leverage the International Space Station or be free-flying. NASA must also communicate its forecasted needs in LEO to allow the private sector to anticipate that demand in their business cases. With this vision, NASA is able to share the cost of a LEO platform with other commercial, Government, and international users. This allows NASA to maximize its

resources toward missions beyond LEO, while still having the ability to utilize LEO for its ongoing needs. In the President's FY 2019 Budget Request, the runout is as below:

- FY 2019 -- \$150M
- FY 2020 -- \$150M
- FY 2021 -- \$175M
- FY 2022 -- \$200M
- FY 2023 -- \$225M

- b. What performance measures will be used to determine whether or not those objectives were met?

Answer: Performance measures are under active development. These measures will focus on the degree to which the program's purpose (as described in ANSWER 2a above) is achieved. Commercial LEO Development will advance the Nation's goals in LEO and exploration by furthering development and maturity of the commercial space market to enable private industry to assume roles that have been traditionally Government-only, and to potentially realize cost savings to the Government by leveraging private industry innovation and commercial market incentives.

- c. What specifically will the \$150 million be used for in Fiscal Year 2019?

Answer: To achieve the Commercial LEO Development program's goals, a first activity will be to solicit inputs from industry on the development and operations of private on-orbit modules and/or platforms and other capabilities that NASA could utilize to meet its long-term LEO needs as one of many customers. NASA is laying the groundwork for 2019 by working with industry in 2018 (including an industry day May 1, 2018) and releasing small study contracts focused on understanding how the commercial sector can be incentivized to support NASA's Low Earth Orbit needs. Based on these initial inputs, NASA expects to then conduct an open competition for public and privately funded module(s) and/or platform(s) attached to the ISS or free-flying in LEO, or other capabilities in FY 2019. NASA also intends to use a portion of these funds to continue to stimulate non-NASA demand for LEO activities that will be needed to support private LEO platforms. The Agency will leverage best practices from other commercial programs as applicable.

3. At present, NASA is the largest user of microgravity research capabilities in low-Earth. Proposed funding for ISS research, which includes microgravity research as well as efforts to develop an advanced space suit, is about \$357 million in FY 2019. If \$350 million per year is a gross estimate of a baseline market in low-Earth orbit, is it enough to support private or commercial research platforms in low Earth orbit? What level of annual net revenue would be needed to sustain a “commercial” space station?

Answer: Note that NASA actually spends considerably more than \$350M in LEO. The true cost of research is much higher, but that most of these costs are “overhead” costs booked in other programs, including ISS operations and crew and cargo transportation. Part of the intent of the LEO Commercial Development Program is to reduce this “overhead” cost, but even with reduction, the total amount NASA spends will be considerably larger than \$350M. NASA expects to have ongoing needs in LEO for its own research, technology demonstration, and crew operations that are intended to be part of a broader commercial market in LEO where NASA is one of many customers. As non-NASA utilization of the ISS National Lab and interest in LEO continues to expand, some initial assessments of potential revenue-producing activities have been conducted by CASIS, NASA, and the Science and Technology Policy Institute (STPI). Estimates for revenues from these activities vary widely depending on many assumptions – operating costs of the platform, revenue models, magnitude of forecasted demand, future transportation costs – making it difficult to make projections as to the viability of these or other potential markets that might emerge. Though NASA is seeing an increase in new users that suggests a promising trend, today’s projections conclude that it is unlikely that these activities will have matured to the point where they can sustain a private platform and their own transportation costs to LEO by 2024 without significant ongoing Government support, which could potentially be satisfied by NASA’s own ongoing LEO needs.

In their 2017 assessment of the viability of a private LEO platform, under the direction of OSTP, STPI examined four boundary scenarios based on high/low platform cost and high/low projected revenues. The diagram below provides the results of those 4 boundary scenarios which informed the conclusions described above.

Cost	High	Low Revenue \$455 M High Cost \$2,250 M Annual Loss = -\$1,795 M	High Revenue \$1,187 M High Cost \$2,250 M Annual Loss = -\$1,063 M
	Low	Low Revenue \$455 M Low Cost \$463 M Annual Loss = -\$8 M	High Revenue \$1,187 M Low Cost \$463 M Annual Profit = +\$724 M
		Revenue	
		Low	High

Annualized Cost and Revenue Estimates for a Private Space Station as analyzed by the Science and Technology Policy Institute

4. What should NASA's role be in bolstering the commercialization of space activities in low-Earth orbit beyond those that address its own requirements? How extensive should that role be in light of continued budget conditions that constrain or result in the elimination of existing high priority agency initiatives?

Answer: The Commercial LEO Development effort is a high priority agency initiative. It begins a new program to encourage development of new commercial LEO platforms and capabilities for use by the private sector and NASA. In encouraging a commercial LEO space economy, NASA plans to obtain services from private industry at less cost than would be possible with Government-owned and -operated capabilities. This will enable the Agency to focus its development efforts on other high priority Agency initiatives.

5. During the hearing, after acknowledging the gap in astrophysics data caused by the elimination of WFIRST, you indicated that you thought that there were "other ways to get that same data". What are those "other ways"? Please provide an identification (list) of astrophysical observatories that will meet the same high-priority scientific objectives that WFIRST is planned to meet, consistent with the decadal survey recommendation.

Answer: NASA is partnering with ESA on the Euclid mission, scheduled to launch in 2021, which will address some of the scientific objectives (e.g., the nature of dark matter and dark energy) of WFIRST. The new Webb Telescope, TESS, and competed missions supported by the proposed budget will add data critical to meeting other high-priority

scientific goals. However, this combination of missions cannot replace the science that would be achieved with WFIRST.

6. With the proposed reduced level of funding requested for Aeronautics in FY 2019, NASA will be able to support just one new X-plane initiative, the supersonic Low Boom Flight Demonstrator. The proposal represents a significant shift from the cadence of one new X-plane every three to five years in the FY 2018 Budget Request. This is not consistent with our urgent need to counter the growing threat posed by other countries who are making higher investments in aeronautics R&D. During the hearing, in your response to a Member's question, you gave a glimpse of future X-planes NASA has planned, such as a subsonic demonstrator which you acknowledged was not in the FY 2019 budget. Under the FY 2019 budget request, what is the cadence in X-planes that you expect to reach? What funding levels would enable NASA to achieve a cadence of a new X-plane every 3 years?

Answer: The FY 2019 budget request fully supports the Low Boom Flight Demonstrator X-plane which will demonstrate quiet overland supersonic flight and open a new market to U.S. industry. On April 2, 2018, NASA awarded a competitive contract for the detailed aircraft design, build, and validation of this X-Plane. The LBFD X-Plane is expected to achieve first flight by FY 2021. Initial flight activities will be focused on the safe expansion of the flight envelope, but NASA will then proceed to conduct a sonic boom noise testing flight campaign. This campaign will generate data that will validate models used to design future airplanes with quiet supersonic features while also giving regulatory authorities a basis on which to set new supersonic noise regulations.

NASA has made significant advances in subsonic technologies that radically reduce fuel consumption, noise, and emissions. Among the key technologies are high aspect ratio wing, boundary layer ingestion engines, new aircraft configurations, and electric propulsion. NASA will build upon the significant advances in recent years and further explore some of the most promising technologies to ensure that they can be used by industry for future products. NASA will develop these enabling technologies through physics-based simulations, ground test, and flight tests in relevant environments where appropriate. For example, NASA will demonstrate the efficiency and feasibility of highly integrated distributed electric propulsion technology through a series of phases using the X-57 general aviation scale aircraft, with flights in 2018 and 2019. Other future flight demonstration opportunities will be evaluated as our research progresses.

7. What is the funding in the FY 2019 budget request specifically focused on Nuclear Thermal Propulsion? What is the projected funding for the period of FY 2020 through FY 2023? What are the greatest obstacles to using Nuclear Thermal Propulsion and to what extent can the planned five-year investment that is currently envisioned address these obstacles?

Answer: NASA has been pursuing a three-year risk reduction activity (FY 2016 to FY 2018) to address several key technology challenges in developing nuclear thermal propulsion, including:

- Fabricating high-temperature fuel elements that minimize erosion and accompanying fission product release and which use lower quantities of enriched uranium than those developed for past programs;
- Testing and qualification of the fuel elements;
- Maturing both reactor and engine system designs;
- Devising a safe and affordable engine ground test and qualification approach;
- Facility challenges with getting enough thermal power into the non-nuclear simulated reactor will increase uncertainty that test results will be representative of the physics present in a full engine; and
- Critical technology required to achieve near zero boil off for long term on-orbit cryogenic hydrogen storage.

Given the remaining technical challenges as well as earlier delays resulting from needing to address an indemnification issue with the fuel element contractor, NASA has decided to extend the nuclear thermal propulsion risk mitigation phase an additional year through FY 2019. This risk mitigation phase will culminate in a System Feasibility Review to determine whether the technology challenges have been sufficiently addressed and the benefits of developing a nuclear thermal propulsion stage are sufficient to merit proceeding with the next phase of concept development.

Exploration Research and Technology intends to invest approximately \$53M in FY 2019 for Nuclear Thermal Propulsion, Cryogenic Fluid Management technologies required to support long-term space storage and management of liquid hydrogen necessary for NTP implementation and other contributing activities. Funding beyond FY 2019 will be determined based on the results of the System Concept Review.

8. Last year, when NASA unveiled the Deep Space Gateway concept, it projected transporting the Solar Electric Propulsion (SEP) portion of the Gateway as part of the EM-2 mission. In the FY 2019 budget request, NASA proposes to send the SEP in 2022 using a commercial launch vehicle.
- a. Assuming NASA will acquire the SEP competitively, can a SEP be ready for launch by calendar year 2022?

Answer: NASA anticipates that under the current schedule, the solar-electric Power and Propulsion Element (PPE) can be ready for launch by 2022.

- b. What impact would a delay in putting an SEP in cislunar space be on the Lunar Orbital Platform plans? What has changed in transportation requirements that now allows the use of a commercial launch vehicle?

Answer: NASA's current plan is that the PPE provide propulsion, orbit controls, power, and communications functions as the first element of the Gateway. A delay in the deployment of the PPE could potentially delay integration of subsequent elements and completion of the Gateway, but the option of using commercial launch vehicles provides NASA the ability to accelerate the launch, provides a dissimilar redundancy of launch systems, and lowers the near-term launch cost. The Agency plans to consider competitively procured commercial launch vehicles to support future robotic missions to cislunar space, including logistics supply flights to the Gateway.

- c. Assuming NASA determines the SEP to be a critical component for the Platform, how confident are you that there will be adequate time to certify the commercial launch vehicle to carry high risk government payloads?

Answer: The Power and Propulsion Element (PPE) is planned for launch on an industry-partner-provided commercial launch vehicle. The industry partner will conduct a spaceflight demonstration of the PPE. At the conclusion of the spaceflight demonstration, it is planned that NASA would have the option to acquire the PPE for use in the Gateway. Thus, no launch vehicle certification is required.

9. The FY 2019 budget request proposal indicates that commercial and international involvement would have a role in NASA's programs, especially the Exploration Campaign. For example, the budget proposal notes that commercial and international partners would be part of the Lunar Orbiting Platform, that commercial entities would be sending payloads to the lunar surface, and that commercial companies might possibly use portions of the ISS for commercial services or develop commercial space stations. What are NASA's plans for handling liability and indemnification matters with respect to commercial partnerships on such activities?

Answer: NASA recognizes that emerging commercial spaceflight systems as well as new and established international partner capabilities can play a valuable role in the achievement of NASA cislunar and surface goals while addressing the goals of the 2010 National Space Policy, as amended by Space Policy Directive-1, and commercial endeavors. NASA is actively engaged with domestic companies involved in the Next Space Technologies for Exploration Partnerships (NextSTEP) contract, and studies with international space agencies building on the ISS partnership. In addition, NASA has released an RFI on mid to large landers designed to obtain additional information from domestic industry on their lander concepts and evolution paths toward human landers.

The concept studies and results of the RFI are designed to inform Exploration Campaign planning to identify potential future roles for partnerships. Capabilities, contributions, and objectives vary widely across potential domestic and international partners. As understanding of a diverse set of partnership roles mature, NASA will be able to formulate specific plans for handling liability and potential indemnification within applicable law and policy.

- a. If a module or rover is conducting both NASA and commercial activities, does the service provider need “authorization” or a license to carry out such activities to be consistent with our treaty obligations?

Answer: While NASA missions do not require a license, licensing requirements exist at the Federal level for commercial activities. Article VI of the Outer Space Treaty requires that the activities of non-governmental entities be subject to “authorization and continuing supervision....” Therefore, if purely commercial activities were planned to be a part of a given mission, then NASA understands that a license or authorization would be required for that portion of the mission, in order to be consistent with the international obligations of the United States. If NASA had no involvement in the commercial activity, then NASA would not control or monitor that activity.

- b. With the potential for shared government and private missions, whose safety requirements must the provider meet—NASA’s or the Federal Aviation Administration’s? Please provide details that will enable the Committee to have a full understanding of not only the funding being requested for the Exploration Campaign but the potential liability exposure to the Federal Government for any activities the Campaign would entail.

Answer: For launch or reentry, the question of safety requirements and liability exposure for Government and/or private missions turns on whether the Federal Aviation Administration (FAA) has licensed the particular launch or reentry.

FAA Licensed Launch or Reentry: As part of the FAA licensing process, launch service providers must demonstrate compliance with FAA ground and flight safety requirements. Liability is handled in accordance with the Commercial Space Launch Act (CSLA) at 51 USC 50901 *et seq* and its implementing regulations at 14 CFR 415 *et seq*. The CSLA contemplates two types of liability – Government property and third party – and has implemented a three-tiered liability regime to deal with each. A launch service provider must purchase insurance to cover both types of liability, commensurate with a Most Probable Loss (MPL) calculation, which quantifies the financial loss associated with a launch mishap. Any amount above this MPL calculation is subject to FAA’s “indemnification” via a Congressional request for further appropriation, up to

\$1.5B (adjusted annually for inflation). Any remaining liability above this statutory cap is borne by the provider.

Non-FAA Licensed Launch or Reentry: For launches or reentries by or for the government, NASA levies applicable range safety requirements and manages liability contractually, rather than through statute or regulation. The launch service contractor interfaces directly with the applicable Range and, as part of the contract, is required to meet those range safety standards. As to liability, NASA maintains comparable protections as provided in the CSLA. For example, currently, the NASA Launch Services contract requires commercial providers to attain \$500M in insurance coverage for third party liability. Damages beyond that would be subject to the NASA Administrator requesting, and the Congress appropriating, additional funds. For damage to Government property, the Government self-insures.

For all in-space activities performed by a commercial partner, NASA's contracts and agreements levy safety requirements as appropriate, and allocate liability and risk between the Government and its partners and address any insurance requirements. For damage to Government property, the Government self-insures. Activities for the Exploration Campaign are in the planning stage. Safety requirements and liability allocation will be assessed as part of this planning process. Finally, liability between NASA and its contractor is apportioned by regulation (48 CFR 1828.371) and provides for reciprocal waiver of claims when NASA and its contractor or partners are engaged in protected space operations. This clause applies both during launch as well as during on-orbit activities.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

“An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2019”

Mr. Robert M. Lightfoot, Jr., Acting Administrator, National Aeronautics and Space Administration (NASA)

Question submitted by Ranking Member Eddie Bernice Johnson, House Committee on Science, Space, and Technology

1. In its FY 2019 budget highlights, NASA states that the budget “Refocuses existing NASA activities towards exploration, by redirecting funding to innovative new programs and providing additional funding to support new public private partnerships.” One of the activities proposed for elimination is NASA’s Office of Education, including its MUREP, EPSCoR, and Space Grants programs.
 - a. Were any analyses conducted that recommended the elimination of the Office of Education and its MUREP, EPSCoR, and Space Grants programs? If so, please provide them.

Answer: The President’s FY 2019 budget proposes the elimination of NASA’s Office of Education and its portfolio of domestic assistance awards (grants and cooperative agreements), and prioritizes funding toward supporting an innovative and inspirational program of exploration. For nearly 60 years, NASA’s mission successes have inspired the world. The Agency will continue to inspire the next generation by leveraging opportunities to engage students in NASA’s work and providing support to educators and educational institutions.

As part of the Agency’s Business Services Assessment, a disciplined approach to strategically perform an assessment of business and mission support services, NASA performed a rigorous assessment of the agency’s work in education and outreach, which included gathering and analyzing a broad and extensive set of data. As a result of this effort, the Agency made a decision on October 2017 to adopt a set of recommendations which included a new direction for science, technology, engineering, and mathematics (STEM) engagement, a new agency-wide STEM engagement function.

Through this strategic approach, working with the mission directorates, NASA will focus on: creating unique opportunities for students to contribute to NASA’s work in exploration and discovery; building a diverse future STEM workforce by engaging students in authentic learning experiences with NASA’s people, content, and facilities; and strengthening understanding by enabling powerful connections

to NASA's mission and work. A new governance council will be accountable for the strategic direction and coordination of the Agency's STEM engagement efforts as the Agency continues to look for efficiencies to improve current operations.

Additionally, in March 2018, GAO found that federal STEM education efforts are fragmented across 163 programs and 13 different agencies that spent \$2.9B in FY 2016. Nearly all of these programs overlapped with at least one other program. The Administration is reviewing how to improve the effectiveness of the government-wide portfolio of STEM programs.

- b. How many students will be affected on an annual basis by the elimination of the Office of Education, MUREP, EPSCoR, and Space Grants? Please provide a breakdown by each program area as well as a total number.

Answer: In FY 2017, the NASA Office of Education, through the EPSCoR, MUREP, SEAP and Space Grant programs, supported approximately 2,672 Institutions, which serve 842,097 students. Additionally, there were 5,921 higher education students receiving significant direct awards through these projects (i.e., \$3,000 – \$5,000 in support or 160 hours of participation in an activity). This data is based on NASA's preliminary education performance reports for FY 2017, which are currently undergoing final review and validation. Note that some institutions participated in multiple projects and activities. However, we do not have sufficiently detailed data in all categories to remove the duplication in the numbers below:

NASA Education Project:	# of FY17 Institutions Served	# of FY17 Students Served	# of FY17 Significant Direct Awardees
Established Program to Stimulate Competitive Research (EPSCoR)	533	*N/A	*N/A
Minority University Research and Education Project (MUREP)	516	32,360	1,019
National Space Grant College and Fellowship Program (Space Grant)	998	719,437	4,672
STEM Education and Accountability Project (SEAP)	625	90,300	230
TOTALS**	2,672	842,097	5,921

* EPSCoR is a research project designed to enhance the research competitiveness of targeted jurisdictions (i.e., states, territories, and commonwealths) by strengthening STEM capacity and capability. While EPSCoR does not provide direct awards to students, EPSCoR researchers do utilize Ph.D. level students as research assistants.

**Some institutions participated in multiple projects and activities, so the totals may include some double counting.

2. The FY 2018 budget request proposed cancelling work on several Earth science instrument and mission activities including the PACE mission, the CLARREO Pathfinder, the OCO-3 mission, and the Earth science instruments on the operating DSCOVR space weather spacecraft. Because we have not settled on an Omnibus appropriations bill for FY 2018 and have been proceeding for almost six months on Continuing Resolutions, no Earth science activities have been terminated and the work has been proceeding. I understand that OCO-3 has been completed and is in storage. What is the justification for proposing their cancellation at this point, especially in light of the fact that work has been proceeding and developments have progressed?

Answer: The FY 2018 Omnibus Appropriations Bill (H.R. 1625) was passed by Congress on March 23, 2018, after submission of this question. The bill fully funds continued operations of the DSCOVR Earth observing instruments EPIC and NISTAR through FY18, as well as continued development of PACE and CLARREO Pathfinder for all previously planned activities, and completion and launch of OCO-3. In particular, the fully tested and flight-ready OCO-3 will be delivered briefly to storage by May 2018 as originally planned, and then further delivered to the launch site for processing and launch as manifested on SpaceX CRS-17.

- a. Was the science community consulted?

Answer: Not directly; however, the previous Earth science decadal survey served as an input in the budget process for the FY18 Request. The 2007 Earth science decadal survey did not recommend OCO-3 or the Earth instruments on DSCOVR. Formulation of the Administration's budget includes a detailed Agency analysis and resolution of competing programmatic priorities at a particular time. The final Administration budget balances priorities and constraints.

- b. What would be the impact to the measurement priorities identified in the recently released Earth science decadal survey of cancelling these missions, especially PACE?

Answer: The 2017 Decadal Survey recommended that the NASA elements of the defined Program of Record (Appendix A of the Decadal Survey) be developed, launched, and operated on schedule and within budget. Operation of the DSCOVR Earth observing instruments EPIC and NISTAR until FY 2020, along with completion and launch of PACE, OCO-3, and CLARREO-PF (all by FY 2022) were explicitly part of the Decadal Survey's Program of Record. However, the Decadal Survey was based on budget assumptions provided during the previous Administration. The current Administration is assuming different budget assumptions and other priorities for NASA.

In the case of each FY 2019 proposed termination, other existing and planned missions from NASA, NOAA, and international partners are providing or will provide similar – though not overlapping – measurements:

1) OCO-3 is designed to make frequent, accurate, and moderate-resolution measurements of atmospheric carbon dioxide levels from the International Space Station (ISS), mapping as many as 100 different areas each day, collecting data at different local times. The existing NASA OCO-2 mission monitors carbon dioxide concentrations and distributions from a sun-synchronous orbit that allows measurements nearly to the poles. International space agency partners from Japan (GOSAT and GOSAT-2), Europe (MERLIN, likely Sentinel-7), among others, have carbon monitoring missions on-orbit and in development.

2) PACE is designed to be the first satellite mission to collect global, hyperspectral measurements of the Earth's integrated ocean and atmosphere system. Existing multi-spectral, long-term, on-orbit U.S. instruments include MODIS on Aqua and VIIRS on Suomi-NPP and the OLCI on the European Sentinel-3A launched in February 2017, with a similar instrument on Sentinel-3B launched in April 2018. These currently provide ocean color measurements with accuracy, stability, and coverage sufficient to enable some NASA research and applications development.

3) CLARREO-PF is a one-year demonstration for the larger, more expensive CLARREO mission, which would provide higher accuracy observations across the full reflected solar and infrared spectra than existing instruments including CERES (on Terra, Aqua, Suomi-NPP, and JPSS-1) and TSIS, which provide basic measurements indicating radiation balance trends. In addition, the CLARREO mission would have performed inter-calibration on orbit in the

reflected solar wavelength domain (to establish an on-orbit reference for existing sensors).

4) NASA-supplied Earth observing instruments EPIC and NISTAR on the orbiting DSCOVR mission provide data on cloudiness and cloud evolution, albedo, ozone and other parameters; and terminated NASA funding would impact NASA research activities related to the scientific analysis of data from the instruments. DSCOVR is operated by NOAA and data could continue to be acquired by both instruments and telemetered back to the ground at NOAA's discretion. EPIC complements (at lower spatial resolution) the measurements of MODIS and VIIRS; and NISTAR complements CERES for albedo and radiation balance.

3. A few months ago, NASA announced that the James Webb Space Telescope had experienced issues in the observatory's final integration and that this would cause a delay to the planned October 2018 launch date. The U.S. Government Accountability Office (GAO) just issued a report concluding that it was likely that the launch date would be delayed beyond NASA's estimate of March to June 2019. GAO also concluded that the congressionally-mandated cap to JWST's development cost of \$8 billion would be at risk of being breached.

- a. Based on your knowledge of this program, is GAO right? Is a delay beyond June 2019 likely and, as a result, will the cost cap be exceeded?

Answer: The Webb launch date will be delayed past the March to June 2019 window, and its development cost estimate is likely to exceed the \$8B development limit. In March 2018, the Webb Standing Review Board (SRB) assessed the project's plans for the time and cost necessary to complete development. The SRB estimated at a 70 percent confidence level that launch-readiness will be approximately May 2020. NASA is convening an external independent review board (IRB) to evaluate all factors, including those identified by the SRB as influencing JWST's success, to ensure that NASA's approach to completing I&T, the launch campaign, and the commissioning of the Webb Telescope is appropriate for NASA's next flagship observatory. NASA will review the SRB & IRB analyses, along with other inputs, to determine updated schedule and cost estimates. NASA plans to submit a detailed report to the Committee by the end of June 2018.

- b. GAO reported that the JWST Program is convening its own review board and that a report is planned for mid-April 2018. In the meantime, have you personally discussed this issue with the prime contractor's top management? What information was conveyed? Are there any penalties that can be levied, at this point, on the prime contractor to ensure that another slip does not occur, should

yet another new launch have to date be established following the review board findings?

Answer: Yes, I have personally discussed this issue with the prime contractor's top management. For several years now, NASA has conducted regular phone calls at the Administrator/CEO level with Northrop Grumman. These calls include the Goddard Center Director. In addition to these regular discussions, I have been in contact with the Northrop CEO to express my deep concerns about their company's performance over the past 12 months. I have asked that senior company officials become directly involved in Webb. As a result, we now have Northrop Grumman COO/President and Senior VPs participating in biweekly schedule progress teleconferences with senior leadership of the Science Mission Directorate. In these teleconferences the Northrop Grumman program manager reviews the current schedule, any issues that threaten that schedule, opportunities to mitigate schedule liens, and upcoming activities.

The NASA JWST Standing Review Board (SRB) conducted their review March 13 and 14, and the contractor was very cooperative in provided the requested information to the SRB. The contractor provided detailed information on activities on the repair of the spacecraft propulsion system (which is now complete) and of the minor tears in the sunshield that resulted from the initial deployment tests (also complete), lessons learned from the initial sunshield deployment tests, upcoming I&T activities, and the updated schedule to allow for upcoming I&T activities, which includes lessons learned and margin.

Contractor performance is graded through their periodic award fee determinations. They are graded in the areas of technical performance, cost, schedule, and business management; to date, a total of \$26M in fee has been withheld from the contractor based on performance. NASA will continue to use the contract award fee mechanism to grade contractor performance, and NASA will continue to ensure that any financial mechanisms used to motivate contractor performance do not introduce unacceptable mission risk.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

“An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2019”

Mr. Robert M. Lightfoot, Jr., Acting Administrator, National Aeronautics and Space Administration (NASA)

Question submitted by Representative Mo Brooks, House Committee on Science, Space, and Technology

1. The NASA Independent Review Team SpaceX CRS-7 Accident Investigation Report Public Summary, released on March 12, 2018, indicated that a “design error” led to the CRS-7 failure. Specifically, the report indicates that SpaceX chose an “industrial grade (as opposed to aerospace grade)” part and integrated that part “without adequate screening or testing of the industrial grade part, without regard to the manufacturer’s recommendations...and without proper modeling or adequate load testing of the part.”

- a. Why was this report not released until almost three years after the accident?

Answer: Since this was an FAA licensed flight, NASA was not required to complete a formal final report or public summary of the accident. NASA believes it is important to have a public record available for industry and users, thus NASA completed the public report on a noninterference basis with our other work. The information needed from the investigation was available as needed to the internal NASA team and the public summary was completed as time allowed. The delay in providing a public summary was a matter of mission priority and workload.

- b. Why was the same ORB-3 IRT report released so much faster?

Answer: The NASA IRT Orb-3 Executive Summary was produced about a year after the Orb-3 mishap. This is not an unusual timeline to complete an investigation and produce a public report when the investigation team can focus on the report writing activity. The NASA team that conducted the independent investigation of the Orb-3 accident and wrote the public executive summary did not have an impending mission to fly using the Antares 130 launch vehicle, therefore they were able to dedicate the necessary effort and time to compose their public summary in a more timely fashion.

For the SpaceX CRS-7 mishap, the NASA IRT, in addition to conducting and concluding the investigation, also had an immediate launch campaign for the Jason-3 mission using a Falcon 9 version 1.1 launch vehicle – the same variant of launch vehicle that had experienced the mishap on CRS-7. After conducting a very thorough investigation, as is evidenced by the public summary, the NASA IRT produced a detailed briefing of their investigation findings, and this briefing

was what NASA used for its own purposes to share lessons within NASA and with SpaceX, and to be able to fly the Jason-3 mission in a timely and successful manner. NASA briefed Congressional House and Senate staff on 7 Jan 2016, and the Jason-3 mission successfully flew on the last Falcon 9 version 1.1 launch vehicle on 17 Jan 2016.

For a public report similar in content to that produced for the OATK Orb-3 failure, NASA began work on the SpaceX CRS-7 “Public Summary” in the summer of 2017. In order to generate this report, the voluminous material needed to be summarized, then reviewed and approved to remove the ITAR/Export Controlled and SpaceX Proprietary information. The “*NASA Independent Review Team SpaceX CRS-7 Accident Investigation Report Public Summary*” recently completed the review process and was published on 12 March 2018.

- c. Is NASA concerned that an increased reliance on potentially lower grade commercial products will result in added risk to the success of crewed missions?

Answer: NASA’s Commercial Crew Program has prioritized crew safety throughout its development and certification phases, including the Certification Products Contracts (CPC) and Commercial Crew Transportation Capability (CCtCap) contracts with industry. NASA is working the insight and oversight requirements in the CCtCap contracts and will ensure commercial crew transportation systems meet the Agency’s safety and certification requirements or that waivers to those requirements are accepted based on informed risk.

- d. What steps is NASA taking so that future incident reports do not have such a delay?

Answer: NASA has usually been able to meet the one year timeline to produce a public summary after a mishap, especially when NASA is responsible for conducting the mishap board. The CRS-7 case was unusual. NASA was not responsible for conducting the mishap board, but chose to do an independent investigation. NASA produced its report at the appropriate time to meet internal and external needs for the data.

2. The Zuma payload was allegedly lost because a Falcon upper stage failed to separate from the payload. What would happen to crew in the future if another upper stage failed to separate from the Dragon crew capsule? Would crew survive? Is NASA addressing this contingency?

Answer: NASA does not comment on non-NASA missions such as the Zuma mission. NASA has worked carefully and diligently to assure our safety requirements span all mission phases and adequately address all credible hazards, including pad emergencies, in-flight aborts and emergency landings.

3. Is NASA considering allowing SpaceX to fuel the Falcon 9 launch vehicle with crew already on board Dragon in order to save money? Or, has NASA already made the decision not to fuel a launch vehicle while crew is on board?

Answer: NASA is evaluating the appropriate time, to be determined by a thorough analysis of risks, to put crew on board for SpaceX's specific system design. Risks need to be considered not only for the flight crew, which has the option for rapid egress utilizing the launch abort system, but also for the safety of crews on the ground during fill operations. There is no scenario without risk. NASA will conduct a thorough trade study analyzing the overall risks and make an informed decision on the timing of crew and propellant loading. This analysis is in work and data from cargo flights is actively being utilized in this analysis.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

“An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2019”

Mr. Robert M. Lightfoot, Jr., Acting Administrator, National Aeronautics and Space Administration (NASA)

Question submitted by Representative Ed Perlmutter, House Committee on Science, Space, and Technology

1. The FY 2019 budget cuts funding for the Restore-L mission which will demonstrate the ability of robotic systems to refuel Landsat-7. Space-based robotics and refueling could not only extend the lifetime and utility of satellites, but could also help execute future human space exploration missions to Mars. Can you explain why the Administration opposes the flight demonstration of this technology?

Answer: NASA has proposed restructuring its Satellite Servicing efforts due to its duplication with industry and DARPA's Robotic Servicing of Geosynchronous Satellites (RSGS) efforts as well as budget challenges driven both by technical challenges as well as Restore-L's implementation approach, and instead directs the Agency's focus toward an industry-driven public-private partnership approach. With on-going, significant investments from industry to develop commercial satellite servicing capabilities, the Agency seeks to contribute its expertise to drive a broad range of technologies for application on both commercial and government satellites. Through a recent Request for Information, NASA received feedback from industry that supports the case for a public private partnership approach, and confirmed significant intent from industry to incorporate on-orbit servicing into business plans. Thus, NASA believes the most cost-effective approach for the Agency is to leverage this commercial industry interest to enable a flight demonstration of satellite servicing technologies that can then be transferred to industry for multiple applications. This enables the Agency to maintain critical technical expertise, primarily through the satellite servicing team at the Goddard Space Flight Center, while driving technology development efforts toward broader benefit within the nascent commercial satellite servicing industry. This effort can also be done within a more sustainable and cost-effective budget profile, allowing NASA to continue a robust and diversified technology portfolio.

Material requested for the record by Representative Brooks during the March 7, 2018 hearing at which Mr. Lightfoot testified.

Answer:

SpaceX's first flight test, or Demonstration Mission-1, is an uncrewed flight test. There is no ECLSS requirement for the flight test and no waiver necessary. Even so, SpaceX is currently planning to test certain ECLSS system capabilities during its uncrewed flight test, such as the pressure control system, temperature control system, and humidity removal system. In addition, SpaceX will be performing extensive ground testing of all major systems (e.g., ECLSS, space suits, waste management system), as well as testing the integrated system.

As background, when NASA competed the Commercial Crew Transportation Capabilities (CCtCap) contract, it imposed a requirement for a crewed flight test; but, there was no requirement for an uncrewed flight test. However, both CCtCap contract awardees, SpaceX and Boeing, proposed to conduct uncrewed flight tests so that many details of the design of their crew transportation system could be tested before a crewed flight test.

NASA assessed the uncrewed test flight vehicle configurations against the test objectives and jointly agreed with the companies that certain hardware was not required to meet the uncrewed test flight objectives. However, all critical hardware to support the uncrewed demonstration of the crew transportation systems to safely launch, rendezvous, dock, and re-enter will be tested during both providers' uncrewed test flights. A similar approach is being taken for uncrewed test flights with Boeing on the Starliner.

Material requested for the record by Representative Lucas during the March 7, 2018 hearing at which Mr. Lightfoot testified.

Answer:

Prior to the FY 2018 enacted budget, NASA planned to modify the existing Mobile Launcher following EM-1 to accommodate the SLS Block 1B for EM-2. NASA anticipated that 33-months of schedule would be needed after EM-1 for the modification, resulting in a Block 1B launch date of September 2022. Building a second Mobile Launcher will take an estimated 5 years, extending the time to a Block1B launch to late 2023. NASA is currently reviewing opportunities for a crewed EM-2 launch on a Block1 SLS before 2023 and implications on exploration objectives. NASA anticipates that 27-months of schedule would be needed after EM-1 for crew systems to support an EM-2 launch on a Block1, resulting in a launch date of no earlier than mid-2022.

As a result, building a second mobile launcher platform will potentially enable an acceleration in the launch schedule for Exploration Mission 2, the first crewed mission of the Orion spacecraft, by 6-months. It will also allow optimization of the overall design of a Mobile Launcher that is purposefully designed from the outset to accommodate the size, mass, configuration, and utilities associated with an SLS Block 1B. The additional time gained by starting construction earlier will also reduce the overall construction and schedule risk to the first flight of Block 1B. Building a new mobile launcher and changing EM-2 from a Block 1B to a Block 1, will reduce schedule dependency between EM-1 and EM-2 -- which was originally driven by the minimum time (with technical risk) to reconfigure ML-1 from SLS Block 1 to the Block 1B configuration -- from 33 months to 27 months. Mission objectives of EM-2 can be achieved using SLS Block 1 with the ML-1 in the current SLS Block 1 configuration.

The total cost of building a second mobile launcher and purchasing a second human rated Block 1 Integrated Cryogenic Propulsion Stage (ICPS) is roughly \$600M. This amount does not include others costs associated with the launch vehicle or funds already expended on modifying the existing mobile launcher. More detailed cost data is considered Sensitive But Unclassified (SBU).

Material requested for the record by Representative Beyer during the March 7, 2018 hearing at which Mr. Lightfoot testified.

Answer:

NASA intends to continue to sustain and modernize its launch and range assets to support mission objectives. Repairs to supporting range infrastructure will be evaluated and prioritized within the CoF institutional program through risk assessments that evaluate and prioritize mitigations of NASA's highest infrastructure risks across the agency. Missions and programs will continue to make range infrastructure modifications and improvements to meet specific mission objectives.

Sustainment and improvements to NASA's Wallops Range are funded primarily from 2 areas. Major repairs and modernization of underlying supporting infrastructure is funded from NASA's institutional Construction of Facilities (CoF) account. Modifications and improvements to the range infrastructure that support specific program requirements are funded from program accounts. Since 2010, NASA has funded approximately \$108M from the institutional CoF program for repairs and upgrades to the infrastructure supporting the Wallops Range. In the same timeframe, NASA programs have funded approximately \$93M to support range operations and make program specific modifications and improvements to the Wallops Range. Range sustainment and improvements included projects such as: a new surveillance radar, upgrades to the range control center, electrical system upgrades, fire detection system upgrades, construction of a new range fire station, construction of the new Mission Operations Command Center, improvements to the primary range communications hub, runway refurbishment, shoreline replenishment and hardening, relocation of Launch Pad 1, and modifications to the Horizontal Integration Facility.

In addition to these construction and upgrade projects, the Goddard Space Flight Center has invested \$29M in a variety of maintenance and improvement projects across Wallops Flight Facility, which include: WFF causeway bridge repairs, replacement of the fire detection system, seawall repairs, paving and repair/replacement of roadways, sanitary sewer repair/replacement and roof replacements.

NASA plans to continue sustaining and making improvements to the Wallops Range as needed to support NASA missions, including future shoreline replenishment projects and evaluation and repairs to underlying infrastructure. NASA plans for future program specific requirements to be funded by the benefitting programs, such as, payload processing, facilities and launch pad maintenance required by the Launch Services Program at Kennedy Space Center (KSC) or Exploration Ground Systems, also at KSC, as part of their normal processes for maintenance and upgrades as required in future years. The International Space Station (ISS) program is purchasing Cargo Resupply Services (CRS) from providers and therefore would not specifically own any requirements at Wallops. Any of those requirements should be the responsibility of the CRS providers, like Orbital ATK, and Wallops directly. No additional funding is required at Wallops to support the Crew and Cargo Program.

Material requested for the record by Representative Banks during the March 7, 2018 hearing at which Mr. Lightfoot testified.

Answer:

The spacecraft components that have been completed so far include those that were provided to NASA by another agency, and they primarily consist of telescope hardware. The total mass of completed flight hardware is about 660 kilograms out of the 6400 kilograms (about 10 percent) of the current estimate for the total dry mass of the completed WFIRST observatory.

Material requested for the record by Chairman Babin during the March 7, 2018 hearing at which Mr. Lightfoot testified.

Answer:

At the President's Budget level of \$1.16B, Orion's FY 2019 priorities will be to accomplish the EM-1 mission per the new schedule, and the EM-2 first crewed flight in accordance with its Agency Baseline Commitment schedule of flight readiness by no later than April 2023. The third Orion mission is expected to occur beyond FY 2023. Some content for the third Orion mission, such as potentially long-lead component procurements and new mission support content such as docking capability, is not necessary to begin at this time, and was therefore not proposed for FY 2019 execution.

Appendix II

ADDITIONAL MATERIAL FOR THE RECORD

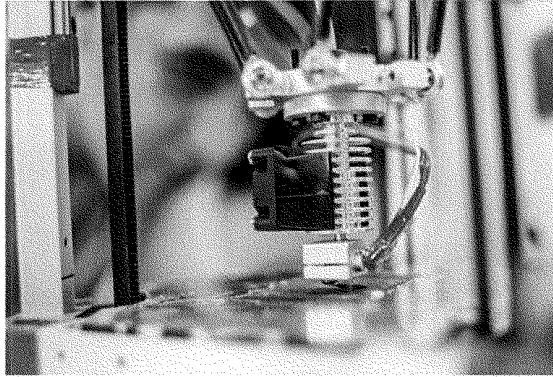
ARTICLES SUBMITTED BY REPRESENTATIVE AMI BERA

<https://www.nytimes.com/2018/01/26/opinion/falling-short-on-science.html>

Opinion | OP-ED CONTRIBUTOR

Falling Short on Science

By MARIA T. ZUBERJAN. 26, 2018



A 3-D printing machine at a China-Ukraine scientific exhibition. China and other countries are making scientific investment a priority.

Credit Oleksandr Rupeta/NurPhoto, via Getty Images

Cambridge, Mass. — Amid the budget turbulence in Washington, it's easy to miss the fact that part of what's at stake is America's dominance in science, engineering and innovation. The United States has been the world leader in these categories for so long that we have stopped believing it could be any other way. But other nations, seeing us lose focus, are seizing the chance to rise.

Scientific and technological leadership doesn't happen by accident. It results from an open political and competitive economic system, from a commitment to recruit and train top talent from all social and economic levels, and from sustained investment. Since World War II, federal investment in research has been a key to keeping the United States at the forefront. Federal dollars have enabled scientists and engineers to investigate advanced ideas and the most unlikely technical solutions, to develop new knowledge before it's clear whether it will be profitable. That new knowledge has revolutionized health care, spawned new businesses and created the digital world. As President Ronald Reagan put it, "although basic research does not begin with a particular practical goal," it's "one of the most practical things government does."

Other nations understand this and are aggressively challenging our lead by trying to copy the United States model. They are making scientific investment a priority and are pushing for partnerships between government, universities and industry.

China is the clearest example. Since 2000, China's spending on research and development has grown by an average of 18 percent each year, while ours grew by only 4 percent. This has placed China a decisive second in R & D expenditures behind the United States, where the government and private sector together invest far more than any other country. Even so, the share of R & D funded by the federal government declined to about 25 percent from just over 30 percent from 2010 to 2015.

Over the next five years, the Chinese government plans to invest 100 times more in artificial intelligence than the United States government did in 2016. And within the past year, China erased the American advantage in supercomputing. It now claims more than 200 of the fastest 500 supercomputers, while the United States has fewer than 150.

How is the United States responding? Despite bipartisan agreement that science and technology investments are critical for our nation, federal science agencies struggle to make long-term plans, stymied by continuing resolutions in Congress that provide only short-term funding for government programs and by stringent caps on both civilian and military spending. Basic research has given us the GPS, the internet, 3-D printing and many if not most other amenities of our modern world. Now, because of budget indecision and inadequate funding levels, federal agencies regularly turn down research proposals that they rate as excellent, and promising young researchers, brimming with ideas, face ever more barriers to establishing their careers.

We cannot continue to advance the frontiers of knowledge and lead the world in innovation without funding for students and equipment, and when the only long-term federal commitment is to fiscal uncertainty.

The generation that propelled us into space is retiring. Both industry and the federal government report that they are unable to find enough workers at all levels with sufficient technical skills. These reports are especially problematic in the national security arena, where employees must be United States citizens. The National Security Agency has experienced significant levels of attrition in jobs requiring substantial technical knowledge.

Other nations are not simply biding their time as we threaten ourselves with stagnation. This is not the moment to stop investing in our future. As President Trump warns in the U.S. National Security Strategy, "Losing our innovation and technological edge would have far-reaching negative implications for American prosperity and power." When investments in R & D produce new scientific and technological advances, those advances can in

turn spawn new companies and even whole new industries, creating good jobs in a variety of fields. We want those jobs in the United States.

Fifty-five years ago, President John F. Kennedy challenged Americans to literally shoot for the moon. His words were met not just with applause on Capitol Hill, but also with years of steady investment in research and education.

Today we face stronger economic and technical competition than we did in 1961. To confront that challenge successfully, the federal government needs to respond with farsighted strategic investment in key aspects of technology, science and education. That will be impossible if government spending caps remain too tight or if agencies are hamstrung for months by fiscal stalemate. To write the next great chapter in the story of our nation, we must continue to fuel discovery.

Maria T. Zuber is vice president for research at M.I.T.

<https://www.nytimes.com/2018/02/07/opinion/international-space-station.html>

Opinion : OP-ED CONTRIBUTOR

Don't Give Up on the International Space Station

By **MARK KELLY**

FEB. 7, 2018

It has been over six years since I last floated in zero gravity through the tunnel that connects the space shuttle to the International Space Station. I visited this orbiting laboratory on four occasions between 2001 and 2011.

Every time I approached the station, I was in awe of its complexity and its beauty. But more than anything, I was in awe of the fact that we had the nerve to even attempt to build something of this magnitude.

It was the United States that led the international coalition of 16 nations to build the space station. Constructing this outpost in outer space took dozens of missions spanning well over a decade to complete, and considerable money. It is clearly one of the more complicated engineering projects humans have undertaken.

It's not perfect and it's not designed to last forever, but what the International Space Station offers humans and nations is remarkable: an important opportunity to collaborate on shared scientific goals, mostly free from politics and almost entirely free from the influences of our planet.

In the years since I left NASA, the space station has started to experience a surge in commercial activity. Two companies, SpaceX and Orbital ATK, now regularly deliver cargo to the station. Just this week, SpaceX launched the Falcon 9 Heavy, a rocket powerful enough to lift 141,000-pound payloads. And after a few years' hiatus, crew members will once again leave American soil for space and make their way to the space station as soon as next year, courtesy of Boeing and SpaceX.

There's more: The aerospace company Sierra Nevada is planning to deliver cargo in the near future. And Bigelow Aerospace has visions of private customers paying to visit the space station, staying overnight in an attached inflatable module built by the company — a hotel in space. The Center for the

Advancement of Science in Space, a nongovernmental organization, now manages commercial science for the space station.

And as the cost of access to low earth orbit continues to decline, more opportunities for commerce in space will emerge, with the International Space Station at the nexus and the United States at the helm.

But all of this will come to a screeching halt (though you won't hear the "screech" in the vacuum of space) if the Trump administration ends funding for the International Space Station program beyond 2024, a [step it is considering](#). The reasons are unclear, though President Trump has said that he wants to prioritize human travel to the moon.

Whatever the priorities, this sort of trade-off is shortsighted. Cutting funding for the station, now between \$3 billion and \$4 billion a year, would be a step backward for the space agency and certainly not in the best interest of the country.

Over the past year, the United States abandoned its leadership position on the global stage in many ways. We stopped leading the effort to combat climate change. We stopped leading on trade and commerce, and raised questions about our continued commitment to multilateral organizations and military alliances. We stopped leading on human rights and the rule of law. If we fail to continue funding the International Space Station, America will sacrifice its rank as the global leader in space exploration and commercial space innovation.

NASA programs have benefited the people of our planet since the founding of the agency in 1958. Solar technology, miniaturized computer chips, CT scans and M.R.I.s are just a few examples of the technologies that were developed and delivered to the American consumer as a result of NASA's innovation.

Because of our country's leadership, we benefited first and we benefited the most. Much more than any other country, in fact. Funding scientific research is one of the most productive ways to put taxpayers' dollars to work. It not only creates jobs but also creates industries that otherwise would never exist. It's easy to see how a dollar spent on our space program is returned to the taxpayer many times over.

Budgeting is about making tough choices, but to abandon one of our most successful and innovative endeavors — one in which we are the global leader — just as it is clearly transitioning to a hub of commercial activity would be extremely shortsighted.

Other countries will undoubtedly fill the void left by American withdrawal — most notably China and Russia, countries we consider significant rivals. Not only would they reap the economic and political benefits of leading in space

but they also could change the direction of the world's collective space endeavors in a way inimical to American interests and values.

If we want our nation to continue leading in space, fully funding NASA's existing programs is absolutely essential. And if we want to some day send astronauts back to the moon or to Mars, we need to fund those efforts as well. It might seem costly in the short term, but the return is well worth the investment.

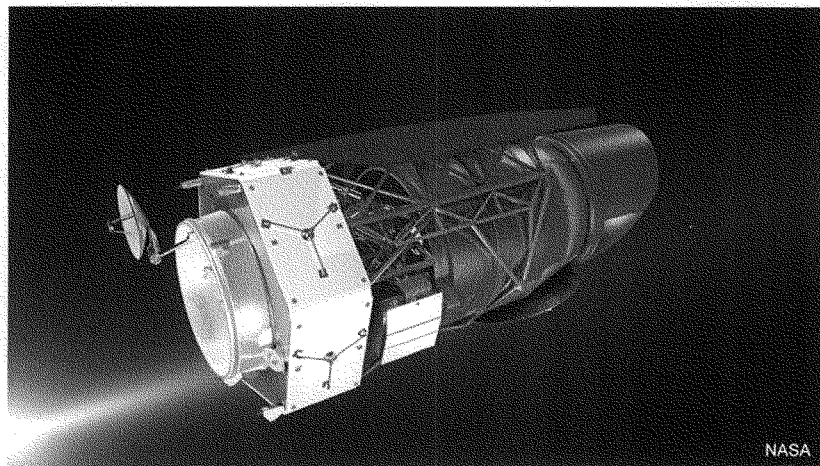
<https://aas.org/media/press-releases/aas-officials-concerned-cancellation-wfirst>

AAS Officials Concerned with Proposed Cancellation of WFIRST

14 Feb 2018

** Contact details appear below. **

Sharing alarm voiced by other scientists, leaders of the American Astronomical Society (AAS) are expressing grave concern over the administration's proposed cuts to NASA's astrophysics budget and the abrupt cancellation of the Wide Field Infrared Survey Telescope (WFIRST). "We cannot accept termination of WFIRST, which was the highest-priority space-astronomy mission in the most recent decadal survey," says AAS President-Elect Megan Donahue (Michigan State University). "And the proposed 10% reduction in NASA's astrophysics budget, amounting to nearly \$1 billion over the next five years, will cripple US astronomy."



WFIRST, the successor to the 28-year-old Hubble Space Telescope and the forthcoming James Webb Space Telescope, is the top-ranked large space-astronomy mission of *New Worlds, New Horizons in Astronomy and Astrophysics*, the National Academies' Astro2010 decadal survey, and is an essential component of a balanced space astrophysics portfolio. Cutting NASA's astrophysics budget and canceling WFIRST would leave our nation without a large space telescope to succeed Hubble and Webb. Yet just last year another National Academies report, *Powering Science: NASA's Large Strategic Missions*, found that "large strategic missions are critical for balance and form the backbone of the disciplines" of NASA's Science Mission Directorate (SMD), which includes astrophysics. The same

report further recommended that “NASA should continue to plan for large strategic missions as a primary component for all science disciplines as part of a balanced program that also includes smaller missions.” “The AAS has long supported community-based priority setting as a fundamental component in the effective funding, management, and oversight of the federal research enterprise,” says AAS Executive Officer Kevin B. Marvel. “This process has been tremendously successful and has led to US preeminence in space science through missions that are now household names, like Hubble.” Marvel continues, “Not only is WFIRST a top decadal-survey priority in astronomy and astrophysics, but the mission has also undergone rigorous community, agency, and Congressional assessment and oversight and meets the high expectations of an astrophysics flagship.” Indeed, after Astro2010, scientific and technological advancements enabled an enhanced WFIRST that would be 100 times more powerful than Hubble. Follow-on National Academies’ reports in 2013 and 2016 reaffirmed the significant scientific merit of the enhanced WFIRST mission, and their recommendations for careful monitoring of potential cost and schedule drivers led to NASA’s commissioning of the WFIRST Independent External Technical / Management / Budget Review (WIETR) last fall.

Neither the commissioning of the WIETR nor the content of its findings are an indication that WFIRST is experiencing or will experience the cost overruns that the Webb telescope experienced. In fact, the opposite is true. As Thomas Young, former director of NASA’s Goddard Space Flight Center and former president and chief operating officer of Martin Marietta Corp., testified to the House Science Subcommittee on Space in December 2017, that WFIRST has undergone extensive scrutiny is “no cause for panic. What is transpiring is a perfectly healthy process to assure that the scope, cost, and risk are appropriately defined.”

NASA’s SMD Associate Administrator, Thomas Zurbuchen, fully agreed with the WIETR recommendations to match mission cost with appropriate resources as part of a balanced astrophysics portfolio. After undergoing a redesign over the last several months, WFIRST would once again fit both within the February 2016 budget approved by NASA at the onset of its mission formulation phase and within the notional five-year budget profile the administration requested for NASA astrophysics in its FY 2018 budget less than one year ago. Put another way, the lifecycle cost for WFIRST is the same now as it was two years ago and has been described as both reasonable and credible by numerous review panels.

Marvel worries that the administration’s proposal to scale back federal investment in the nation’s exploration of the universe and terminate WFIRST risks undermining future decadal surveys and other community-based priority-setting processes. “These efforts to achieve community consensus on research priorities are vital to ensuring the maximum return on public and private investments in the astronomical sciences,” Marvel says. “The cancellation of WFIRST would set a dangerous precedent and severely weaken a decadal-survey process that has established collective scientific priorities for a world-leading program for a half century. Such a move would also sacrifice US leadership in space-based dark energy, exoplanet, and survey astrophysics. We cannot allow such drastic damage to the field of astronomy, the impacts of which would be felt for more than a generation.”

The AAS will defend the important role of the decadal surveys in helping set federal spending priorities, to explain the scientific promise of the top-ranked WFIRST mission, and to share our excitement for the field of astrophysics, which has never been more ripe for discovery from the search for life elsewhere in the universe to understanding where we came from and where we’re going. “We look forward to working with Congress to restore funding for WFIRST and for NASA astrophysics overall,” Donahue concludes.

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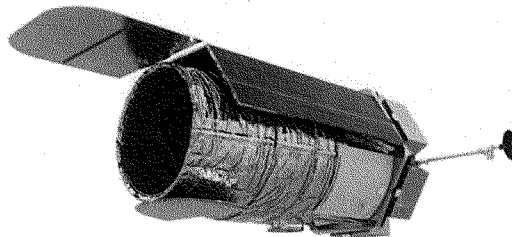
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The American Astronomical Society (AAS), established in 1899, is the major organization of professional astronomers in North America. The membership (approx. 8,000) also includes physicists, mathematicians, geologists, engineers, and others whose research interests lie within the broad spectrum of subjects now comprising contemporary astronomy. The mission of the American Astronomical Society is to enhance and share humanity's scientific understanding of the universe, which it achieves through publishing, meeting organization, education and outreach, and training and professional development.

<https://blogs.scientificamerican.com/observations/canceling-nasas-high-priority-missions-bad-policy-bad-precedent-bad-for-science/>

Canceling NASA's High-Priority Missions: Bad Policy, Bad Precedent, Bad for Science

By Ellen Stofan, Waleed Abdalati on February 21, 2018



....Credit: NASA, Goddard Space Flight Center WFIRST Project Wikimedia

The president's recently released Fiscal Year 2019 budget gives NASA an overall increase in funding—certainly something to celebrate in the current fiscally constrained environment. Clearly, however, with so much NASA could do that is inspirational, important and innovative, there will always be choices and tradeoffs to be made. With that in mind, the National Academy of Sciences, Engineering, and Medicine (NASEM) developed a process to help the federal government prioritize science at NASA. Every 10 years, the organization brings science communities together to produce documents that explicitly lay out the scientific priorities and missions that NASA should execute in the coming decade in various areas: astronomy and astrophysics; planetary science; heliophysics; Earth science; and science conducted on the International Space Station.

As former NASA chief scientists, we have been intimately involved in making these kinds of hard choices, and these so called decadal surveys, with their carefully

developed, community-based recommendations, have been tremendously valuable tools for ensuring those choices are made responsibly and most effectively. But the current budget proposal cancels several high priority missions recommended in decadal surveys, undermining a 50-year-old process that has long had bipartisan support from the executive and legislative branches of government along with the scientific community. These cancellations could potentially damage our ability to understand our own planet and the universe that surrounds us.

In 2010, NASEM released its latest decadal report, titled “New Worlds, New Horizons in Astronomy and Astrophysics”, which ranked the Wide Field Infrared Survey Telescope (WFIRST) as its highest space-based priority. WFIRST would follow on from the Hubble Space Telescope and the James Webb Space Telescope (JWST, to be launched next year). With a hundredfold bigger field of view than Hubble, it would help scientists tackle problems from the nature of dark energy to the evolution of galaxies, and could directly image worlds around other stars to investigate their properties.

Big telescope missions like WFIRST take years of instrument development and testing. To have the capability to explore the farthest reaches of the universe in place in the mid 2020s and capitalize on the findings of JWST, therefore, requires investments today. Despite the fact that significant investment has already been spent on its development, WFIRST has been defunded in the president’s FY19 budget proposal, threatening to create a gap of unknown length, and potentially ending the U.S.’s leadership in the exploration of deep space.

The previous Earth Science decadal survey, published in 2007, listed as its highest priorities missions to study ocean color (which is indicative of the uptake of carbon dioxide from the atmosphere); clouds and aerosols (small particles that affect Earth’s climate); and heating processes in Earth’s atmosphere. All three of these high priority missions have also been canceled in the FY19 budget proposal. Underscoring the disregard for carefully chosen priorities is that fact that the most recent Earth science decadal survey (released in 2018) reaffirmed the importance and prioritization of those items, which are currently under development as a result of NASA’s efforts to adhere to the 2007 decadal survey.

Moreover, as with WFIRST, a significant amount of the development costs of these missions has been invested already. The net result is that not only will missions aimed at addressing some of the highest priority observations be cancelled, but investments to date will be wasted, and the benefits of such investments unrealized. Such actions are neither scientifically nor economically prudent.

Each decadal survey takes about two years to complete and ultimately involves hundreds of scientists and a thorough peer-review process. Hundreds of white papers are submitted by the scientific community to allow for an open and comprehensive survey of the key scientific challenges in a given field. Decadal survey panel members spend long hours debating which measurements and missions would allow for

substantive progress in addressing questions of primary importance—and which of these are technically ready to be flown in the coming decade. In the process, they make hard choices about what priorities should and should not be recommended for support in the face of the fiscal realities that all agencies face. Survey recommendations carefully take into account not just realistic budget projections, but recommendations as to possible paths of action if budgets increase or decrease.

Canceling missions that are top priority decadal recommendations is not good policy, and will damage our ability to understand the planet we live on, and our search for habitable worlds beyond Earth. We urge the scientific community and the public to stand behind the NASEM decadal process as the best, most nonpartisan, method to determine NASA's science spending priorities. Otherwise we undermine a process that has been carefully thought out to serve the nation's interests by ensuring that U.S. taxpayer dollars go towards addressing the most significant scientific and societally beneficial challenges.

ABOUT THE AUTHOR(S)

Ellen Stofan

Ellen Stofan is a former NASA chief scientist and Principal at Insight Earth LLC.

Waleed Abdalati

Waleed Abdalati is a former NASA chief scientist, and director of the Cooperative Institute for Research in Environmental Sciences at the University of Colorado, Boulder.

LETTER SUBMITTED BY REPRESENTATIVE ED PERLMUTTER

March 2, 2018

The Honorable Lamar Smith
 The Honorable Eddie Bernice Johnson
 House Committee on Science, Space, and Technology
 2321 Rayburn House Office Building
 Washington, DC 20515

Dear Chairman Smith and Ranking Member Johnson:

I am writing you today with a grave concern for the technological future of NASA. Unfortunately, the President's FY19 NASA Budget request guts the very research and technology development that is needed to accomplish the bold missions the Budget includes.

Specifically, the proposed re-organization of the "Space Technology Mission Directorate" into "Human Exploration" within NASA is among the most devastating long-term aspects proposed. Past history has shown that large development programs and technology development activities cannot and should not exist together, as a small hiccup in the development programs eats the budget of the basic research and technology advancement needed to accomplish more in space. In fact, when integrated in this manner approximately a decade ago, NASA's space technology activities were eviscerated.

Most striking, the Administration is proposing this re-organization without any discussion with Congress, industry or the university community, and without a NASA Administrator in place. This can only be described as an egregious over-reach by political appointees without an appreciation for the long-standing scope of the Agency. This proposal contradicts Title 7 of the space policy put forward by Congress and signed by President Trump in March 2017. Burying this proposed organizational change in the FY19 budget request, while simultaneously proposing other major cancellations and changes to the NASA portfolio, is an attempt to curtail community discussion of the importance of the Space Technology Mission Directorate to the nation's future in space.

In order to halt this re-organization until further deliberations can take place, I suggest writing a letter from Members to the Administration – much like the [letter](#) from Senators Cruz and Nelson about the International Space Station cancellation.

There are 4 over-arching reasons that this proposed re-organization should be stopped:

- 1) **Space Technology Works:** Over the past decade, Space Technology has demonstrated that a portfolio approach is critical to technology development. In this manner, technology is matured from concept to flight demonstration to mission infusion. There are multiple examples of space technology products being matured and infused into the Agency's missions, including mission-critical advancements in thermal protection systems, space communications, aerodynamic decelerators, and advanced chemical, solar electric and nuclear propulsion technology that are advancing Orion, the Agency's science missions, and it's future human exploration goals.
- 2) **NASA's Breadth in Missions:** At its core, NASA is a technology Agency, and a symbol of U.S. technological superiority in the world. As such, NASA must have the capability to invest in the nation's future. The goal of Space Technology is to mature and infuse disruptive technology solutions into the nation's future space missions. Such investments are outside the mission-focused horizons of the HEO and Science mission directorates. There are significant cultural, workforce development, and practical reasons to manage technology development activities distinct from major spaceflight hardware development programs. These programs, which have different goals and timelines, are well

served by distinct management approaches. The Agency's Science and Exploration missions are linked in their common need for advanced technology. Focusing NASA's technology efforts solely on human lunar exploration is effectively a ~\$200M cut to the Science Mission Directorate's future.

3) **Hurting the NASA Workforce:** There are too many good people at the NASA Centers doing technology development to not have a champion at the highest levels. This proposed re-organization will curtail innovation at the NASA Centers. Space Technology is an investment in the core capabilities of the NASA Centers. It is the major source of funding to keep the Centers on the cutting edge and grow new capabilities. Without these investments, the NASA Centers will cease to innovate and the Agency will ultimately be left behind. Without being on the cutting edge itself, NASA will become unable to objectively evaluate disruptive solutions put forward by industry and academia that could dramatically impact our future in space.

4) **We Need a Forward Leaning Space Program:** This move is the same as that made in the 2005 timeframe. That 2005 decision is the primary reason NASA's leadership in technology development is just now starting to come back. NASA and the nation need a space technology program that is the envy of the world, not one buried within the bowels of the bureaucracy. At a time in which China, Europe, Russia, India and multiple countries in the Middle East are increasingly investing in space technology, the U.S. should make its investments in this arena more, not less, visible.

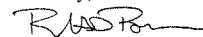
Space Technology has been previously authorized by multiple Congresses in a bipartisan manner (2010, 2012, 2017), appropriations have been relatively stable, and technology products are flowing into future Agency and industry missions. This proposed change will ultimately cut off this critical technology pipeline and lead to an Agency that is left-behind in the space arena, a domain which is increasingly sophisticated and being impacted by global technology disruption.

Space technology leadership is more important today than it was a decade ago, and such investments will be even more important for our nation's future in space. The proposed movement of the Space Technology Mission Directorate into Human Exploration will curtail our nation's leadership in space technology, adversely impacting the economic competitiveness, national security and quality of life impacts so important to our society and our leadership position in the world.

Please use your oversight authority of NASA to halt any plans for a re-organization of its four mission directorates (HEOMD, SMD, ARMD and STMD) until Congress has time to consider this matter, industry and the university community have been consulted, and a NASA Administrator is appointed, confirmed by Congress, and in place as the leader of the Agency.

I would be happy to discuss this matter with you further at any time.

Sincerely,



Bobby Braun

Dean of the College of Engineering and Applied Science, University of Colorado Boulder
Former NASA Chief Technologist, 2010-2011

cc:

The Honorable Brian Babin, Chairman, Subcommittee on Space
The Honorable Ami Bera, Ranking Member, Subcommittee on Space

LETTER SUBMITTED BY REPRESENTATIVE DANA ROHRABACHER



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March 3, 2018

Committee on Science, Space, and Technology
Subcommittee on Space

Dear Committee Members:

Let me thank this committee for its insightful support of NASA's Space Technology Mission Directorate and for its leadership in ensuring NASA's technology future through funding for its carefully conceived technology-development programs. As a small-business owner, faculty member at Cornell University and former Chief Technologist for NASA, I am deeply troubled by the elimination of the Space Technology Mission Directorate in the President's 2019 budget proposal. A robust, carefully administered and independently managed technology-development enterprise is essential for NASA. Space Technology is that essential enterprise. It will enable the agency to realize the bold future that the President envisions. Funding it in its current form will keep NASA's entire exploration and science portfolio on track, keeping the US at the forefront of space technology, and ensuring that the economic benefits of space will continue to accrue to all of us.

The goal of Space Technology is to mature and infuse disruptive technology solutions into the nation's future space missions. Such investments are outside the mission-focused horizons of the human space and science mission directorates. Operational directorates are generally incentivized to make use of the best available and focus on their applications. So, they rarely accept greater risk for potentially dramatic improvement. A NASA study in 2005-2006 showed clearly that large development programs and technology development activities cannot coexist in the same organization, as a small overrun in near-term programs eats the seed corn--the budget of the technology advancement needed for the future. In fact, when integrated in this manner approximately a decade ago, NASA's lost its edge in space technology, as development activities were eviscerated, setting back our Nation's capabilities in space exploration and science.

It's not only NASA that has successfully implemented this model. The aerospace industry does the same: Lockheed Martin's Advanced Technology Center and Northrop Grumman's NG Next are both technology programs that separate their forward-looking research portfolios from near-term operational programs for these very reasons: they recognize the competitive value of long-term investment in intellectual property. That's the role of Space Technology at NASA.

Particularly troubling is that NASA has already begun dismantling Space Technology. It has begun to study how to embed its responsibilities within some other mission directorate, such as Human Exploration and Operations. This direction is a gravely misguided. That's because the scope of HEO's successful technology programs, Advanced Exploration Systems (AES) and the Human Research Program (HRP)—despite being extremely well-run—differ fundamentally from Space Technology's. AES advances technologies that directly impact the near-term needs of the directorate. In contrast, Space Technology engages in the cross-cutting technology development that no single mission directorate prioritizes. And yet the technologies it develops, such as solar-electric propulsion and cryogenic propellant storage and transfer, are critically important for future science and exploration missions.

Let me offer a contrasting example: the Advanced Stirling Radioisotope Generator, which had been a project funded within the Science Mission Directorate (SMD), was cancelled a few years ago largely because it had too many advocates outside SMD—HEO saw it as an option for surface power (on Mars or the Moon)—and as a result, the precious mission-driven technology funding in SMD was redirected toward other SMD specific efforts. So, cross-cutting technology development within the mission directorates is generally unlikely to be sustained.

Space power, asteroid mining, solar sails, and many other forward-looking concepts receive support from Space Technology. So do next-generation lunar-exploration capabilities. The NASA Technology Roadmaps contain all of these technologies, and many more. They are reviewed externally (through the National Academies) every few years to identify what NASA could invest in. Then, through the NASA Technology Executive Council, all the mission directorates work to establish Space Technology's priorities. This process works. And it works well because Space Technology brings in the best ideas to NASA, wherever they may be found: from small businesses, traditional aerospace contractors and universities, and from NASA's own experts. These diverse voices keep NASA innovative.

Through this sort of innovation, Space Technology blends what we call "mission pull" and "technology push." The former refers to technology needs driven by specific programs; the latter introduces unexpected solutions that ultimately lead to better missions. The mission directorates, appropriately, focus on "pull" technologies. If Space Technology is dismantled or moved, the cross-cutting innovations will wither on the vine and will be the first to be sacrificed when budget overruns or future mandates from OMB force funding to be redirected.

It may be that OMB is proposing this change because it believes Space Technology to be unfocused. If so, OMB misunderstands. Only about 8% of Space Technology goes to the blue-sky, early stage work (the long-term investments, only a few of which ever become everyday technologies). Even for the early-stage work, in all cases, Space Technology leadership consults with downstream customers about their needs and gaps and brings them to the table when they consider awarding contracts. The rest of Space Technology is even more customer-centric. From my point of view, Space Technology is already set up to support HEO's lunar objectives (as well as SMD and in some cases ARMD). The more mature technology projects in the Space Technology portfolio are trying to do exactly that. If anything, the other mission directorates can improve by working more closely with Space Technology.

Except for a few years in the mid-2000s, NASA has always had an organization that brings the technology future to the present. Please restore Space Technology to its place in NASA, an independent voice for innovation that serves as NASA's SpaceX. I hope this letter is useful in informing your discussions as you exercise your oversight responsibilities, ensuring the integrity of NASA and future of the nation's space program.

Respectfully,



Mason Peck
President & CEO
Tannhauser Gate LLC