Description of document:	National Aeronautics and Space Administration (NASA) Questions for the Record 2016-2020
Requested date:	23-May-2020
Release date:	03-June-2020
Posted date:	15-June-2020
Source of document:	FOIA Request NASA Headquarters 300 E Street, SW Room 5Q16 Washington, DC 20546 Fax: (202) 358-4332 Email: hq-foia@nasa.gov

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

June 3, 2020

Reply to attn. of: Office of Communications

Re: FOIA Tracking Number 20-HQ-F-00545

This responds to your Freedom of Information Act (FOIA) request to the National Aeronautics and Space Administration (NASA), dated 5/23/2020, and received in this office on 5/28/2020. You seek:

A copy of the Questions For the Record (QFR) and agency QFR responses to Congress responding to QFRs during calendar years 2017, 2018, 2019 and 2020 to date, for NASA. These records are likely found in the NASA office that handles legislative affairs/congressional relations.

In response to your request we conducted a search of NASA's Office of Legislative and Intergovernmental Affairs (OLIA) using the search terms QFR, Hearing, 1/1/2017 - 5/29/2020. That search identified the enclosed records that are responsive to your request. We determined that all 515 pages are appropriate for release without excision and copies are enclosed.

Appeal

If you believe this to be an adverse determination, you have the right to appeal my action on your request. Your appeal must be received within 90 days of the date of this response. Please send your appeal to:

Administrator
NASA Headquarters
Executive Secretariat
ATTN: FOIA Appeals
MS 9R17
300 E Street S.W.
Washington, DC 2054

Both the envelope and letter of appeal should be clearly marked, "Appeal under the Freedom of Information Act." You must also include a copy of your initial request, the adverse determination, and any other correspondence with the FOIA office. In order to expedite the appellate process and ensure full consideration of your appeal, your appeal should contain a brief statement of the reasons you believe this initial determination should be reversed. Additional information on submitting an appeal is set forth in the NASA FOIA regulations at 14 C.F.R. § 1206.700.

Assistance and Dispute Resolution Services

If you have any questions, please feel free to contact me at Stephen.G.Rowe@NASA.gov. For further assistance and to discuss any aspect of your request you may contact:

Stephanie Fox
Chief FOIA Public Liaison
Freedom of Information Act Office
NASA Headquarters
300 E Street, S.W., 5P32
Washington D.C. 20546
Phone: 202-358-1553
Email: Stephanie.K.Fox@nasa.gov

Additionally, you may contact the Office of Government Information Services (OGIS) at the National Archives and Records Administration to inquire about the FOIA mediation services it offers. The contact information for OGIS is as follows: Office of Government Information Services, National Archives and Records Administration, 8601 Adelphi Road-OGIS, College Park, Maryland 20740-6001, e-mail at ogis@nara.gov; telephone at 202-741-5770; toll free at 1-877-684-6448; or facsimile at 202-741-5769.

Important: Please note that contacting any agency official including myself, NASA's Chief FOIA Public Liaison, and/or OGIS is not an alternative to filing an administrative appeal and does not stop the 90 day appeal clock.

Sincerely,

Stephen Rowe

Stephen Rowe
FOIA Public Liaison

Committee on Oversight and Government Reform
Subcommittee on Information Technology
November 16, 2016

"Federal Cybersecurity After the OPM Data Breach: Have Agencies Learned their Lesson?"

Representative Robin Kelly, Ranking Member
Questions for the Record

Question 1:

What functions of your agency are met by using third–party IT services such as commercial cloud computing? Is cybersecurity a reason why such third party services are acquired? How do you evaluate cybersecurity of the commercial services compared to technologies developed within your agency?

Answer 1:

NASA uses commercial cloud computing for applications and services that provide scientific data analysis, helpdesk and ticket management, mobile device management, project management, data center backups, and collaboration tools. Some primary reasons for NASA's cloud adoption include: leveraging ad-hoc computing resources at a lower cost long-term than owning; operating, and maintaining traditional hardware and software; consolidating and eliminating physical data center infrastructure in favor of managed cloud infrastructure; and, taking advantage of emerging, scalable, and cost-effective solutions that exist in the cloud rather than procuring and deploying additional on-premise hardware and software.

NASA believes that cloud computing has the potential to be more secure than on-premise deployments, especially with large scale providers like Amazon Web Services and Microsoft, because they are able to make significant investments in securing a homogenous infrastructure. Additionally, consumption of cloud (where individuals must be granted controlled access and provisioned specific roles) has a tendency to be more structured and controlled than on-premise operations.

NASA secures its physical technologies and information systems in accordance with security controls outlined in the National Institute of Standards and Technology (NIST) Publication 800-53 security compliance requirements established in the Federal Information Security Modernization Act (FISMA). NASA applies the same level of rigor towards security assessments, authorizations, and monitoring of cloud-based technologies in accordance with NIST 800-53 and FISMA requirements to address the cloud model's shared security responsibilities requirement.

Question 2:

What changes are necessary to the Federal Risk and Authorization Management Program (FedRAMP) to enable it to adopt more innovative, secure infrastructure?

Answer 2:

One innovation that could improve the FedRAMP program is "FedRAMP Light" – an initiative to enable vendors of Software as a Service (SaaS) tools that present low risk to obtain a FedRAMP certification with reduced cost and effort, assessing a tailored number of the most important NIST security controls. The General Services Administration is currently exploring this option and NASA encourages its adoption. Another innovation would be to modify the FedRAMP mandate and associated messaging to reflect a clear acknowledgement of these certification challenges from a risk perspective that emphasizes reasonable assurance. For example, FedRAMP should provide clear leeway and approval for Federal agencies to leverage other appropriate third-party certifications (e.g., International Standards Organization (ISO), Statement on Auditing Standards (SAS), etc.) for cloud tools in the absence of a FedRAMP approval so long as agencies demonstrate that the system is secure with a reasonable level of assurance (i.e., conducting an agency-specific risk assessment in accordance with policy and accepting residual risk if and where appropriate).

Question 3:

Are there security and accreditation improvements that will encourage federal agencies to increase their utilization of the cloud for better security?

Answer 3:

As a trend, many people are still skeptical of cloud computing. Some organizations struggle to accept using cloud computing because of the belief that cloud computing is not as secure as traditional, on-premise deployments.

The most important thing that can be done to increase cloud adoption is to make more cloud products available with verified cyber security and law enforcement controls quickly so agencies can increase adoption rates to meet mission and business requirements. The above mentioned efforts, for example, would enable FedRAMP approval to be seen less as a bottleneck and more as a partner for delivering secure cloud services for Federal consumption. Vendor trends will help to the extent that many are already eliminating on-premise versions of their software. Soon, many products will be only available in cloud versions.

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

January 4, 2017

Reply to Attn of: OLIA/2017-00001f:SWQ:eel

The Honorable William Hurd
Chairman
Subcommittee on Information Technology
Committee on Oversight and Government Reform
U. S. House of Representatives
Washington, DC 20515

Dear Chairman Hurd:

Enclosed are written responses to questions submitted by Representative Connolly resulting from the November 16, 2016 hearing entitled, "Federal Cybersecurity After the OPM Data Breach: Have Agencies Learned their Lesson?"

This material completes the information requested from Representative Connolly during that hearing.

Sincerely,

Seth Statler

L. Seth Statler
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosure

Committee on Oversight and Government Reform
Subcommittee on Information Technology
November 16, 2016

"Federal Cybersecurity After the OPM Data Breach: Have Agencies Learned their Lesson?"

Representative Gerald E. Connolly
Questions for the Record

PART I:

Over the past few years we have heard of several significant data breaches and unauthorized exfiltration of sensitive data across the government. While we are addressing our failures in the past by enhancing our network and perimeter security, concerns have been raised that we are failing to address how we protect sensitive data within and outside our networks.

QUESTION 1:

What steps/measures are you considering that are data-centric, as opposed to perimeter-based or otherwise, to ensure the privacy and security of data and preventing data exfiltration in the event of an intrusion?

ANSWER 1:

NASA is improving its data-centric security capabilities by deploying several key projects and programs such as the Federally-deployed Continuous Diagnostics & Mitigation (CDM) program that will significantly enhance NASA's cybersecurity posture. CDM phase 1 tools will improve NASA's ability to identify and assess data from a risk management perspective, and thereby enhance protection to specific assets and data. NASA performs regular analysis of attacks by monitoring major attack types at the Agency. We regularly test ourselves via external, third-party penetration tests and data-exfiltration exercises to evaluate our capabilities and evolve our security network.

QUESTION 2:

What is your ability to (cryptographically) protect data at rest, in transit, and in use?

ANSWER 2:

NASA has implemented a Data-at-Rest (DAR) encryption solution for applicable end user devices including desktops, laptops, and mobile devices (smart phones/tablets). Server to user endpoint communication (Data-in-Transit) for applications and data transmission is configured to use encrypted communication protocols such as HTTPS/Secure Socket Layer (SSL/TLS) and Secure Shell (SSH). The Agency continues to adapt to the ever-changing threat environment and is exploring potential solutions for Data-in-Use (DIU) encryption.

QUESTION 3:

Do you have any mechanism to protect sensitive data from improper access by highly privileged users such as system administrators?

ANSWER 3:

NASA has the ability to protect sensitive data from improper access on a case-by-case basis for selected systems. Highly privileged users such as system administrators receive alerts, encryptions, and annual trainings. Furthermore, event logging and alerts provide advanced protection to the Agency. Data-at-rest encryption (i.e., ENTRUST) can ensure only selected approved individuals can access a piece of sensitive information. This, along with separation of duties, will eliminate unapproved users access to sensitive information. Additionally, NASA provides annual role based training for administrators. Training allows administrators to stay informed and up to date with information regarding the protection of highly sensitive data.

QUESTION 4:

What ability do you have to detect improper data access by authorized users (*i.e.*, in an anomalous and possibly malicious manner)? Do you have proactive capabilities in this area, or only after-the-fact, forensic capability (or neither)?

ANSWER 4:

Without getting into security sensitive information, NASA discovers improper data access via forensic detection during audits and incident response. NASA is currently researching approaches for insider threat detection and is actively working with the Department of Homeland Security to implement a prototype insider threat capability. If the prototype is successful, insider threat detection tools will have the ability to detect anomalous user behaviors as they access data systems across the Agency.

QUESTION 5:

Do you have the ability to share sensitive data across your organizational boundary with authorized recipients and still protect it?

ANSWER 5:

Yes, NASA has the ability to share sensitive data across our networks in a secure environment. The Agency has several secure data collaboration capabilities with our partners that are tested and utilized on a regular basis.

QUESTION 6:

How do you measure use of or attempts to use data – successful or otherwise - that has been the subject of a breach, as opposed to simply reporting the number of records that have been breached?

ANSWER 6:

NASA has a Threat and Vulnerability Assessment team of analysts that receive threat intelligence data from a multitude of sources specific to NASA events and data. The team investigates any alleged postings/release/use of NASA data and logs it as an incident. If the release is tied to a data breach from a previous incident, the two events will be associated and marked as related, and this is tracked and measured as part of NASA's incident records.

QUESTION 7:

What monitoring tools and technologies do you use in advance of learning about a breach to detect and anticipate breaches and attempts to gain access to data?

ANSWER 7:

NASA utilizes incident detection systems for monitoring network events and incident detections. Also, the Agency uses network and domain name server based sinkhole services for preventing and detecting breaches. Intrusion prevention systems are also deployed on NASA's network boundaries, for the prevention of breaches. The Agency maintains a team of analysts who track known Advanced Persistent Threat (APT) actors and campaigns as well as their associated indicators of compromise (IOCs) and behaviors. This data is used in the sensors discussed above as well as proactive efforts to scan our computing environment for signs of previously undetected compromises or attempted compromises.

PART II:

The weakest link in cyber security will always be humans. Whether intentional or unintentional, users typically resist additional security steps and friction in their workflow and often are the target of malicious attacks.

QUESTION 1:

Do you have the ability to transparently encrypt and decrypt data for common file types that your users work with?

ANSWER 1:

Yes. NASA utilizes multiple tools to both encrypt and decrypt data for common file types. These capabilities allow all NASA users the ability to easily send and receive files in a secure manner while maintaining information integrity.

QUESTION 2:

When you encrypt data, do you do this from the moment of creation to the moment of consumption, or do you do this only on backend systems (encrypted database or Hard drive disks)?

ANSWER 2:

NASA currently employs capabilities that encrypt data at its moment of creation, in-transit, and at consumption. The Agency ensures data encryption is available for all users.

QUESTION 3:

Can you revoke access on a granular level to specific documents, people, etc after the document has left your control (e.g. Without having to recall the file and retransmit a new version)?

ANSWER 3:

NASA has not yet implemented specific capabilities to revoke or grant access on a granular level. However, the Agency is prepared for and awaiting the iterative deployment of DHS's Continuous Diagnostics & Mitigation (CDM) capabilities. Successive phases of CDM implementation will allow for a vastly improved access control, behavior, and authentication management infrastructure.

JASON CHAFFETZ, UTAH
CHAIRMAN

ONE HUNDRED FOURTEENTH CONGRESS

ELIJAH E. CUMMINGS, MARYLAND
RANKING MINORITY MEMBER

Congress of the United States
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November 28, 2016

Ms. Renee P. Wynn
Chief Information Officer
National Aeronautics and Space Administration
300 E. Street SW, Suite 5R30
Washington, D.C. 20546

Dear Ms. Wynn:

Thank you for appearing before the Subcommittee on Information Technology of the House Committee on Oversight and Government Reform on November 16, 2016, at the hearing entitled, "Federal Cybersecurity After the OPM Data Breach: Have Agencies Learned their Lesson?" We appreciate the time and effort you gave as a witness before the Committee.

Pursuant to the direction of the Chairman, the hearing record remains open to permit Members to submit additional questions to the witnesses. Attached are questions directed to you. In preparing your answers to these questions, please address your response to the Member who has submitted the question and include the text of the Member's question along with your response.

Please provide your response to these questions by December 13, 2016. Your response should be addressed to the Committee office at 2157 Rayburn House Office Building, Washington, DC 20515. Please also send an electronic version of your response by e-mail to William Marx at William.Marx@mail.house.gov in a single Word formatted document.

Thank you for your prompt attention to this request. If you need additional information or have other questions, please contact Andres Bascumbe of Rep. Gerald E. Connolly's staff at (202) 225-1492, or Mike Flynn of the Majority Staff at (202) 225-5074.

Sincerely,

Will Hurd

Will Hurd
Chairman
Subcommittee on Information Technology

Enclosure

cc: The Honorable Robin Kelly, Ranking Member, Subcommittee on Information Technology

To: Ms. Renee P. Wynn
Chief Information Officer
National Aeronautics and Space Administration

From: Representative Gerald E. Connolly
Member
Subcommittee on Information Technology
Committee on Oversight and Government Reform

November 16, 2016
The Subcommittee on Information Technology
"Federal Cybersecurity After the OPM Data Breach: Have Agencies Learned their Lesson?"

Over the past few years we have heard of several significant data breaches and unauthorized exfiltration of sensitive data across the government. While we are addressing our failures in the past by enhancing our network and perimeter security, concerns have been raised that we are failing to address how we protect sensitive data within and outside our networks.

1) What steps/measures are you considering that are data-centric, as opposed to perimeter-based or otherwise, to ensure the privacy and security of data and preventing data exfiltration in the event of an intrusion?
2) What is your ability to (cryptographically) protect data at rest, in transit, and in use?
3) Do you have any mechanism to protect sensitive data from improper access by highly privileged users such as system administrators?
4) What ability do you have to detect improper data access by authorized users (*i.e.*, in an anomalous and possibly malicious manner)? Do you have proactive capabilities in this area, or only after-the-fact, forensic capability (or neither)?
5) Do you have the ability to share sensitive data across your organizational boundary with authorized recipients and still protect it?
6) How do you measure use of or attempts to use data – successful or otherwise - that has been the subject of a breach, as opposed to simply reporting the number of records that have been breached?
7) What monitoring tools and technologies do you use in advance of learning about a breach to detect and anticipate breaches and attempts to gain access to data?

The weakest link in cyber security will always be humans. Whether intentional or unintentional, users typically resist additional security steps and friction in their workflow and often are the target of malicious attacks.

1) Do you have the ability to transparently encrypt and decrypt data for common file types that your users work with?
2) when you encrypt data, do you do this from the moment of creation to the moment of consumption, or do you do this only on backend systems (encrypted database or Hard drive disks)?

3) Can you revoke access on a granular level to specific documents, people, etc after the document has left your control (e.g. Without having to recall the file and retransmit a new version)?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

May 24, 2017

Reply to Attn of: OLIA/2017-00097:SWQ:dac

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Babin:

Enclosed are responses to written questions submitted by Ranking Member Bera resulting from the March 22, 2017, hearing at which Mr. William Gerstenmaier testified regarding "The ISS after 2024: Options and Impacts."

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"The ISS after 2024: Options and Impacts"

Mr. William H. Gerstenmaier, Associate Administrator, Human Exploration and Operations Missions Directorate, NASA

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

QUESTION 1:

During the question and answer session of the hearing, Dr. Dittmar and Mr. Stallmer indicated that the private sector's ability to develop and operate modules attached to the International Space Station (ISS) will take some time, time that cannot be defined. Establishing a firm cut-off date for operations of the International Space Station has pros and cons.

If additional resources are not provided to extend ISS operations beyond 2024, what would be the downside of letting folks know now that 2024 will be as far as we will go so that they can have certainty in their planning?

ANSWER 1:

NASA, in consultation with its International Partners, will need to make a decision about whether to extend ISS beyond 2024 in the next couple of years. Until that point, however, there is some advantage in remaining flexible with regards to the future of ISS, given the continuing progress being made in ISS research, the evolving nature of the market for commercial low Earth orbit (LEO) services, and the ongoing development of NASA's post-ISS plans. ISS represents a major investment in a unique capability that plays a key role in enabling of our human exploration infrastructure. If the decision is made prematurely to decommission it, America's leadership in human space exploration may be adversely impacted. This could occur if critical exploration research has not been completed on ISS by 2024 and future assets – whether governmental or commercial – are not yet operational. It could also occur as NASA's exploration plans continue to evolve, depending on the Agency's specific requirements in LEO or beyond. Similarly, concluding ISS operations and utilization too soon might undermine the establishment of the commercial LEO economy that NASA has been working to promote. It is important to transition human LEO operations to the private sector, but the handoff must be implemented in a way that supports, rather than jeopardizes, NASA's plans for deep space exploration and the commercial development of LEO. NASA believes that the release of a firm date after which ISS operations will be discontinued, if not accompanied by a significant amount of supporting information about NASA's plans for managing the transition away from ISS, would not provide the certainty desired by the private sector, and could negatively impact the LEO economy.

QUESTION 2:

President Trump has released his budget blueprint for FY 2018, and I understand that the request for NASA includes a cut of $272M to the Space Operations account, which includes the ISS. What is the rationale for the cut and what impact will it have on ISS research and operations?

ANSWER 2:

The President's detailed FY 2018 Budget Request is slated to be released in May, at which point, specific information about the various accounts will be available. NASA is committed to ISS operations and utilization through at least 2024; Station is a key component of NASA's human exploration portfolio, and its requirements will be balanced with those of other elements in that portfolio.

QUESTION 3:

How would an extension of ISS operations beyond 2024 affect NASA's progress on its deep space exploration projects under a potential flat budget scenario?

ANSWER 3:

It is important to note the key role ISS is playing in NASA's mission to extend human presence into the solar system. In order to prepare for human expeditions into deep space, we are utilizing the ISS to conduct research and demonstrate the advanced technology and habitation systems necessary to keep our crews safe and productive on long duration space exploration missions beyond the Earth-Moon system. The decision about whether to extend ISS operations beyond 2024 will take this role into account, and balance it against the requirements for future deep space systems. Regardless of when ISS operations are concluded, NASA has stated that it expects to have ongoing space research and technology demonstration requirements that will require financial support.

QUESTION 3a:

Could NASA sustain a safe cadence of Space Launch System (SLS) and Orion launches and acquire all the other needed systems as part of a deep space human exploration program, while also sustaining ISS operations, if it receives no increased funding?

ANSWER 3a:

NASA is committed to the safe operation of the Space Launch System (SLS) and Orion. The specific balance of ISS operations and utilization (including whether to extend Station beyond 2024), SLS/Orion mission cadence, and pace of development and acquisition of future human space exploration systems will be reflected in future budget requests. The use of international contributions and value of public private partnerships will affect the funding needed.

QUESTION 3b:

What would the flight rate be?

ANSWER 3b:

The SLS is being designed to be capable of supporting a long-term flight rate of one per year with a surge capability to three per year. The actual cadence of missions beyond Exploration Mission-2 (EM-2) will be defined based on mission needs, available resources, and operational costs. NASA's current human exploration planning is consistent with an SLS/Orion flight rate of one per year augmented by commercial and/or international logistics flights.

QUESTION 3c:

Please provide any analysis to the Subcommittee to support your conclusions.

ANSWER 3c:

Please see response to Question #3a, above.

QUESTION 4:

During the question and answer session of the hearing, Dr. Dittmar said that if Station is to continue, *"you're going to have to find ways to reduce costs."* She referred to acquisition reform as being *"one path to being able to reduce cost."* She also mentioned the need to reduce costs in production as well as in operations across the human spaceflight enterprise.

a. What, if any, acquisition reforms is NASA considering and how would they affect ISS or human spaceflight costs?

ANSWER 4a:

NASA continually assesses and, when prudent, makes changes to its acquisition approach. As the ISS operational lifetime policy is developed, NASA will address the implications of each of the ISS Program's contracts, agreements, and future acquisitions. We also continue to assess acquisition options across all of our human spaceflight programs. As part of the President's FY 2018 budget, NASA will support and expand public-private partnerships as the foundation of future U.S. civilian space efforts, to include ISS operations.

QUESTION 4b:

Is NASA making or planning to make cost reductions in the Human Exploration and Operations Directorate that will be applied to the ISS program and operations? If so, where will those cost reductions be made and at what level?

ANSWER 4b:

NASA continues to look for further opportunities to increase efficiencies, to allow us to productively operate and sustain the ISS, keep our crews healthy and safe, and support utilization at lower costs. Ongoing activities to decrease the operations and maintenance cost of the ISS include changes to our contracts to incentivize efficiency, lower overhead cost, and apply targeted enhancements in technology investments to reduce manpower-intensive processes.

QUESTION 4c:

As the ISS ages, do you anticipate that maintenance costs will increase? If so, by how much? If not, why not?

ANSWER 4c:

NASA's budget for ISS includes a balance of systems operations and maintenance; research; and cargo/crew transportation. U.S.-built Station modules were designed for a 30-year on-orbit lifetime. NASA is tracking Station maintenance needs; at this point, a number of Station components are lasting longer than originally anticipated. In addition, enhancements to the baseline ISS systems to increase reliability and thereby decrease crew maintenance time are underway. For example, improvements to some of the life support components that have been more prone to failure are in work. These improvements will not only save precious crew time on ISS, but fill capability gaps for missions beyond LEO. Most spares have already been purchased and maintenance costs are not likely to increase.

QUESTION 5:

When does a decision need to be made on whether or not ISS operations are extended beyond 2024? If no other nation signs on to an extension of operations, could the U.S. go it alone?

ANSWER 5:

NASA, in consultation with its International Partners, will need to make a decision about whether to extend ISS beyond 2024 in the next couple of years. It is important to note that NASA and its International Partners are dependent on each other for the operations, resupply, and maintenance of the ISS.

NASA and Roscosmos are mutually reliant on one another in the operation of the ISS. NASA will continue to need Russia-unique critical capabilities not currently available elsewhere, such as: propellant and propulsion systems for desaturation of the rate gyros, reboost, phasing burns and debris avoidance maneuvers; redundant life support for U.S. systems; sustaining engineering for the Russian-built, U.S.-owned Functional Cargo Block (FGB); goods and services related to Russian Segment systems training for on-orbit ISS operations; supplies and sustaining engineering on the Russian-built toilet in the non-Russian segment; and potential de-orbit assistance. Roscosmos will continue to need NASA capabilities including:

electrical power for Russian core systems and payloads; redundant life support for Russian systems; attitude control; communications downlink telemetry and commanding to augment limited Russian ground site coverage; and training for non-Russian Segment operations. The other partners are not as critical as Russia to day-to-day ISS operations. Some of the dependencies on Russia can be mitigated. For example, U.S. cargo vehicles could supply reboost and control-moment-gyro desaturation capability. Life support system redundancy could come from the new exploration systems planned to be tested on ISS.

QUESTION 6:

Does NASA need a sustained capability for research or human operations in low Earth orbit (LEO) beyond 2024? If so, what are the requirements for that research?

ANSWER 6:

NASA expects to have ongoing research and technology development requirements that will require financial support, but the nature and magnitude of these requirements has not yet been defined. NASA is currently assessing its long-term requirements for LEO research, technology development, and utilization beyond 2024. NASA plans to complete the majority of its research and technology development for deep space exploration around 2024. Research areas such as life sciences, physical science, astrophysics, and other areas are being assessed. NASA is actively working transition strategies for the 2020s that include the goals of U.S. leadership in space and the development of a viable commercial market in LEO, including the possibility of private platforms. In developing these transition strategies with our International Partners, domestic industry, academia, and Administration and Congressional stakeholders, NASA will take into account the Agency's plans for human deep space exploration.

QUESTION 6a:

Are there Federal government agencies who have expressed a need for a human presence in LEO following the end of ISS operations? If so, which ones?

ANSWER 6a:

NASA defers to other Federal agencies to define their needs, if any, for a human presence in LEO following the conclusion of ISS operations. Although NASA did confer with other U.S. agencies on the benefits of LEO microgravity research, the Agency is not aware of any such requirements.

QUESTION 7:

Does NASA anticipate having a fully operational closed loop environmental control and life support system by 2024? If not, what does NASA need to do now to achieve that goal by that date?

ANSWER 7:

A fully-closed loop environmental control and life support system is not currently feasible, but NASA is seeking to close the loop as much as possible. NASA is using the ISS as a testbed to fill critical gaps in technologies that will be needed for long-duration deep space missions. For example, elements of the ISS life support and other habitation systems, along with contributions from private sector firms, will evolve into the systems that will be used for deep space exploration missions. It is NASA's plan to first develop and demonstrate many critical technology capabilities using the ISS as a permanently-crewed testbed prior to deploying these capabilities beyond LEO. This critical work will continue throughout the operating life of the Station, and will be informed by the ISS Technology Demonstration Plan. The completion of this work is partially dependent on on-orbit performance of the new systems and the available resources to execute the plan. Today, NASA expects to complete these testbed activities on ISS by the 2024 timeframe. Beyond ISS, further validation work on environmental control and life support system technologies and other habitation systems will be carried out on missions in cislunar space.

QUESTION 8:

Your testimony talks about public-private partnerships being the *"foundation of future US. civilian space initiatives."* Partnerships imply that each party has "skin in the game." Currently, NASA pays for all the transportation costs to get commercial payloads to and from the ISS. When will that change, so that commercial ventures can get a realistic understanding of the costs of doing business in LEO?

ANSWER 8:

At this time, NASA plans to continue providing transportation services in support of research being conducted under the auspices of the ISS National Laboratory, as managed by the Center for the Advancement of Science in Space. NASA defers to commercial entities for information on their business plans for commercial facilities in LEO, including those related to transportation to and from such facilities. The Agency is actively developing transition strategies for the post-ISS era and is engaged with the private sector to foster both commercial demand and supply for LEO services, including transportation services. It is NASA's intention to transition LEO to private platforms and capabilities enabled by commercial markets, academia and government agencies, including NASA (should a requirement arise), with interest in LEO research and activities.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
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www.science.house.gov

April 7, 2017

Mr. William H. Gerstenmaier
Associate Administrator
Human Exploration and Operations Mission Directorate
National Aeronautics and
Space Administration (NASA)
300 E Street SW
Washington, DC 20546

Dear Mr. Gerstenmaier,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the March 22, 2017 hearing titled, *"The ISS after 2024: Options and Impacts*."

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than April 21, 2017. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than April 21, 2017.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Rep. Brian Babin
Subcommittee Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"The ISS after 2024: Options and Impacts"

Mr. William H. Gerstenmaier, Associate Administrator, Human Exploration and Operations Missions Directorate, NASA

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

1. During the question and answer session of the hearing, Dr. Dittmar and Mr. Stallmer indicated that the private sector's ability to develop and operate modules attached to the International Space Station (ISS) will take some time, time that cannot be defined. Establishing a firm cut-off date for operations of the International Space Station has pros and cons.

   If additional resources are not provided to extend ISS operations beyond 2024, what would be the downside of letting folks know now that 2024 will be as far as we will go so that they can have certainty in their planning?

2. President Trump has released his budget blueprint for Fiscal Year 2018, and I understand that the request for NASA includes a cut of $272 million to the Space Operations account, which includes the ISS. What is the rationale for the cut and what impact will it have on ISS research and operations?

3. How would an extension of ISS operations beyond 2024 affect NASA's progress on its deep space exploration projects under a potential flat budget scenario?
   a. Could NASA sustain a safe cadence of Space Launch System (SLS) and Orion launches and acquire all the other needed systems as part of a deep space human exploration program, while also sustaining ISS operations, if it receives no increased funding?
   b. What would the flight rate be?
   c. Please provide any analysis to the Subcommittee to support your conclusions.

4. During the question and answer session of the hearing, Dr. Dittmar said that if Station is to continue, "*you're going to have to find ways to reduce costs.*" She referred to acquisition reform as being "*one path to being able to reduce cost.*" She also mentioned the need to reduce costs in production as well as in operations across the human spaceflight enterprise.
   a. What, if any, acquisition reforms is NASA considering and how would they affect ISS or human spaceflight costs?

b. Is NASA making or planning to make cost reductions in the Human Exploration and Operations Directorate that will be applied to the ISS program and operations? If so, where will those cost reductions be made and at what level?
c. As the ISS ages, do you anticipate that maintenance costs will increase? If so, by how much? If not, why not?

5. When does a decision need to be made on whether or not ISS operations are extended beyond 2024? If no other nation signs on to an extension of operations, could the U.S. go it alone?

6. Does NASA need a sustained capability for research or human operations in low Earth orbit (LEO) beyond 2024? If so, what are the requirements for that research?
   a. Are there Federal government agencies who have expressed a need for a human presence in LEO following the end of ISS operations? If so, which ones?

7. Does NASA anticipate having a fully operational closed loop environmental control and life support system by 2024? If not, what does NASA need to do now to achieve that goal by that date?

8. Your testimony talks about public-private partnerships being the "*foundation of future U.S. civilian space initiatives*." Partnerships imply that each party has "skin in the game." Currently, NASA pays for all the transportation costs to get commercial payloads to and from the ISS. When will that change, so that commercial ventures can get a realistic understanding of the costs of doing business in LEO?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

June 22, 2017

Reply to Attn of: OLIA/2017-00182f:swq

The Honorable Lamar Smith
Chairman
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are written questions submitted by Ranking Member Johnson, resulting from the April 26, 2017, hearing at which Dr. Thomas Zurbuchen testified regarding "Advances in the Search for Life."

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosures

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Advances in the Search for Life"

Dr. Thomas Zurbuchen, Associate Administrator, Science Mission Directorate, National Aeronautics and Space Administration (NASA)

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

Question 1:

What steps has NASA taken in response to direction in the recently enacted NASA Transition Authorization Act of 2017 directing NASA to enter into an arrangement with the National Academies to develop a science strategy for astrobiology?

Answer 1:

NASA is currently engaged with the National Academies to finalize the study terms and establish an official contract. We anticipate standing up the committee and beginning the study in June 2017. Once underway, it is expected to take approximately one year to conduct the study, with additional time for peer review as deemed appropriate, and the final report to be submitted to Congress in the September 2018 timeframe.

Question 2:

In February, NASA released new details about its mission architecture for sending humans and robotic landers and rovers to the surface of Mars in the 2030s. While geologists and astrobiologists on the surface of Mars can make quick, intuitive decisions about which samples are most scientifically compelling, humans could introduce the potential for contaminating scientifically important environments. In your view, what are the risks and benefits of involving humans directly in the search for life, such as in carrying out investigations on the surface of Mars? What is NASA doing to characterize such risks so that steps toward mitigating them can be taken?

Answer 2:

Mars is the horizon goal for pioneering space but it is important to note that in this journey, the human and robotic explorers will play a complementary role. While robotic missions will serve as science and technology pathfinders for crewed missions to Mars, astronauts on the surface of the planet will be able to expand our knowledge and inform mission planning for further robotic exploration. Robotic explorers will also better inform future human explorers as to those areas that might be at risk of contamination from terrestrial life, and enable them take appropriate precautions. Astronauts will be able to collect a greater volume and diversity of rock and soil samples than would be possible using robots alone, but the potential to contaminate samples with biosignatures from Earth will be much higher. As was the case with the rock samples collected during the Apollo missions to the Moon, astronauts on the Martian surface will be able to make in situ judgments about samples to be retrieved, and will be able to record the context in which those samples were discovered, as well as the potential for Earth contamination to be introduced. Additionally, we expect astronauts on Mars to be able to analyze orders of magnitude more samples than get returned, and selecting samples with minimal Earth contamination will be important to assure the highest chance to detect signs of Martian life. Careful selection will also enhance other aspects of scientific quality in the samples that are selected to be returned to Earth. Continued robotic exploration of Mars will ensure that areas of the planet not as readily accessible to human crews do not go unexplored.

NASA recognizes there are inherent risks as well as benefits of involving humans directly in the search for life, and our planetary protection and mission planning teams are actively working together to evaluate mitigation strategies. We currently do not know whether the Martian environment contains biohazards that might cause problems for astronauts or affect the environment of the Earth. Under consideration is using sterilized teleoperated robots to explore those areas where contamination from human explorers is a concern for the environment of Mars, or where Earth contamination could interfere with the detection of possible Martian biohazards.

Question 3:

The Curiosity rover was only partially sterilized before going to Mars. How has partial sterilization affected the choice of areas Curiosity is able to explore in terms of addressing scientific objectives related to the search for life? What is the planetary protection category for the Mars 2020 rover? How does such a classification affect the regions of Mars the rover can study and the science it can do?

Answer 3:

Curiosity's primary mission is to assess whether Mars ever was, or is still today, an environment able to support microbial life. Because it was not carrying instruments designed to search for evidence of extant Martian life, Curiosity was designated planetary protection Category IVa and subject to a biological contamination limit. The Curiosity rover complied with planetary protection requirements to carry a total of no more than 300,000 bacterial spores on any surface from which the spores could get into the Martian environment. The categorization of the mission and the resulting restrictions have not inhibited its ability to meet its primary science objectives.

If in the future, a site in Gale crater becomes identified as potentially a Special Region (where terrestrial microbial life might propagate), then Curiosity would be precluded from entering the site until further study determines the site is not at risk for contamination.

NASA has designated the Mars 2020 mission as Planetary Protection Category V: Restricted Earth Return, due to the presence of hardware intended to cache samples for future return to Earth, and appropriate requirements are being implemented accordingly. These include designing the sample collection hardware to meet stringent limits on Earth biological contamination introduced into samples collected for future return. As was the case for Curiosity, the primary constraint for the Mars 2020 mission is the restriction from landing in, entering, or creating, a Special Region on Mars. This should not affect the science results, as the Mars 2020 Science Definition Team report concluded that the primary mission objective of exploring an ancient environment does not require the mission to access Special Regions.

Question 4:

With the recent announcement from NASA of a potential second observation of plume activity on Europa, is there a push to alter the scientific goal of the NASA Europa Clipper mission to include life detection? How would such a decision be made? Is it possible to add life detection instruments to the spacecraft at this point in its development?

Answer 4:

The ultimate aim of Europa Clipper is to determine if Europa is habitable, possessing all three of the ingredients necessary for life: liquid water, chemical ingredients for building biomolecules, and energy sources sufficient to support life. The nine instruments that NASA has selected for the mission will physically characterize the subsurface ocean, interrogate the surface for evidence of materials convected from the subsurface ocean, and chemically characterize that material. If the Europa Clipper encounters a plume, it would be able to make similar measurements to what Cassini was able to do at Enceladus. Analysis of a sample spewed directly from the subsurface ocean would prove more definitive information on the potential habitability of Europa.

Even though some of the nine instruments have limited capability to detect biomarkers, searching for life is easier if done by a lander on the surface or directly accessing the subsurface ocean. A lander payload would need to be designed to detect likely dilute evidence of life that has been lofted to the surface from the ocean deep below.

Question 5:

Last month, NASA announced that Cassini composition measurements revealed the presence of molecular hydrogen in the plume material spewing from the surface of Enceladus, thus providing an "independent line of evidence that hydrothermal activity is taking place in the Enceladus ocean." As you know, hydrothermal activity provides a necessary chemical energy source for life. What future verification and confirmation activities will logically flow from discoveries such as this and how can excitement be sustained until those activities can be undertaken?

Answer 5:

Cassini has completed its data gathering at Enceladus, and the mission will reach its dramatic conclusion this September. But the analysis of Cassini data is far from complete. It will continue for years, fueling scientific advancements and refining our understanding of Enceladus. Coupling this work with research on hydrothermal systems on Earth is a proactive path forward, and the planetary science and Earth oceanographic communities are beginning to work together.

The information Europa Clipper will provide about Europa's ocean will be highly relevant to Enceladus and our search for life on Ocean Worlds. It is not unreasonable to surmise that the geophysics of Enceladus responsible for the observed hydrothermal activity is also operating on Europa. The scientific community is excited to confirm this activity on Europa and perhaps find evidence that some form of life is taking advantage of that hydrothermal energy source.

No further observations of Enceladus and its ocean will be possible until a new mission is launched. Such a mission is one of seven candidate destinations currently under competition in NASA's New Frontiers Program. Initial selections are expected this fall.

Question 6:

What is the status of the NASA Nexus for Exoplanet System Science (NExSS) initiative? What results have come from the initiative and what plans does NASA have for NExSS over the coming years?

Answer 6:

NExSS is a NASA research coordination network dedicated to the study of planetary habitability. The goals of NExSS are to investigate the diversity of exoplanets and to learn how their history, geology, and climate interact to create the conditions for life. NExSS is overseen by representatives from NASA HQ, three co-leads, and a Steering Committee composed of the Principal Investigators (PIs) of 18 funded proposal teams selected to be the founding members of NExSS. These investigators are drawn from a diverse range of scientific backgrounds including astrophysics, Earth science, heliophysics, and planetary science and lead interdisciplinary teams ranging in size from 3 to over 50 members. Specifically, major areas of research focus include exoplanet detection, characterization, planetary formation processes, climatic evolution, paleoclimate and biogeochemistry, as well as microbiology, astrobiology, and the emergence of life. Moreover, NExSS supports two cross-team NASA Postdoctoral Program (NPP) Fellows, as well as a NASA Postdoctoral Management Program (NPMP) Fellow based at NASA Ames Research Center.

In the past year, Affiliate members have also been added to the NExSS network; these are individuals or groups whose research interests and vision are aligned with those of NExSS but who currently do not belong to any of the PI-led teams. Affiliates are invited to participate in NExSS's webinar series, attended conferences and workshops and contribute to science, data, and policy products in order to facilitate wider community engagement.

To date, NExSS has supported three 'Workshops Without Walls' (WwW) focused on the interior evolution of potentially habitable planets, the effect of 'space weather' on long-term planetary habitability, and the detection of remote biosignatures. Participants and speakers have attended in-person but also via weblink as the input and active engagement of remote participants has been emphasized to ensure representation from the wider local and international community. Products from these workshops have included white papers, new collaborations, and the identification of new questions, topics and research avenues. NExSS's most recent workshop resulted in a total of five review papers on the science and technology of remote searches for signs of life on exoplanets. These documents are currently in the stage of community comment and feedback, facilitated through NExSS's online infrastructure, in preparation for eventual submission to *Astrobiology* journal.

It can be difficult to quantify the effectiveness of research coordination networks as many of the successes of these initiatives cannot be easily measured. For example, NExSS's PIs note that several collaborative activities such as student exchanges, winter/summer schools, invited talks at department seminars and colloquia, as well as joint grant proposals have arisen from their interactions with the NExSS community.

Furthermore, organization is currently underway for NExSS's flagship meeting entitled *Habitable Worlds 2017: A Systems Science Workshop*, which will be held in November 2017 in Laramie, WY. This workshop will deviate slightly from the traditional format of science conferences in that emphasis on 'breakout' sessions on topics suggested by the participants are prioritized alongside talks and presentations. The workshop will seek to address broad questions pertaining to planetary habitability including what conditions are needed for habitability, how those conditions arise, and how we can best search for them.

NExSS began as an experiment in cross divisional cooperation and interdisciplinary research focused on habitability and the search for life beyond our solar system. The program has met our expectations and continues to build its impact and reach. As long as it enhances the science, feeds into our missions, and remains productive, NASA will continue to support the system science approach for studying exoplanets.

Question 7:

What is the status of NASA's plans for a future mission to return cached samples collected by the Mars 2020 rover so they can be studied by researchers on Earth? You mention in your statement that NASA is "exploring opportunities to partner with industry to leverage their future missions to advance decadal survey science objectives." Can you expand on that? When can we expect to get more details on when and how cached samples from Mars will be returned to Earth?

Answer 7:

NASA has been studying concepts for returning samples collected by the Mars 2020 rover in the context of a larger Mars exploration architecture assessment, which was called for in the FY17 NASA Transition Authorization Act (PL 115-10). Consistent with the direction in the NASA Transition Authorization Act, this assessment would be conducted by the National Academies of Sciences, Engineering, and Medicine and would use the strategies and priorities described in the NRC Vision and Voyages for Planetary Science in the Decade 2013-2022 [the Planetary Science Decadal Survey] as a starting point. This assessment, which would consider opportunities for collaboration with commercial and international partners, would feed into the Administration's future Mars planning.

This assessment is planned to be completed by Fall 2018.

Question 8:

How do scientific and technological advances in astrobiology impact the way NASA sets its broader astrophysics science goals? In your view, are any changes to this process needed?

Answer 8:

NASA recently created the Nexus for Exoplanet System Science (NExSS) research coordination network to leverage research investments in many fields to understand how planetary processes lead to potentially habitable exoplanets, as well as how the planet stars and neighbor planets interact to support life. This "system science" approach will help scientists better understand how biology interacts with the atmosphere, geology, oceans, and interior of a planet, and how these interactions are affected by the host star. This in turn help us better understand how to look for life on exoplanets. For instance, Earth-observing satellites has given us a wealth of information on the atmosphere of our home world, which we have utilized to 'groundtruth' the models and techniques that astrophysicists will use to analyze the atmospheres of other planets.

Scientific and technological advances in astrobiology will be incorporated into the upcoming 2020 Decadal Science Survey and will be used to set priorities for the next decade of astrophysics research. NASA believes that this process is working well and does not need to be changed.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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May 11, 2017

Dr. Thomas Zurbuchen
Associate Administrator
Science Mission Directorate
National Aeronautics and
Space Administration (NASA)
300 E Street SW
Washington, D.C. 20546

Dear Dr. Zurbuchen,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the April 26, 2017, hearing titled, *"Advances in the Search for Life."*

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than May 25, 2017. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than May 25, 2017.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Lamar Smith

Rep. Lamar Smith
Chairman

cc: Rep. Eddie Bernice Johnson
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Advances in the Search for Life"

Dr. Thomas Zurbuchen, Associate Administrator, Science Mission Directorate, National Aeronautics and Space Administration (NASA)

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

1. What steps has NASA taken in response to direction in the recently enacted NASA Transition Authorization Act of 2017 directing NASA to enter into an arrangement with the National Academies to develop a science strategy for astrobiology?

2. In February, NASA released new details about its mission architecture for sending humans and robotic landers and rovers to the surface of Mars in the 2030s. While geologists and astrobiologists on the surface of Mars can make quick, intuitive decisions about which samples are most scientifically compelling, humans could introduce the potential for contaminating scientifically important environments. In your view, what are the risks and benefits of involving humans directly in the search for life, such as in carrying out investigations on the surface of Mars? What is NASA doing to characterize such risks so that steps toward mitigating them can be taken?

3. The Curiosity rover was only partially sterilized before going to Mars. How has partial sterilization affected the choice of areas Curiosity is able to explore in terms of addressing scientific objectives related to the search for life? What is the planetary protection category for the Mars 2020 rover? How does such a classification affect the regions of Mars the rover can study and the science it can do?

4. With the recent announcement from NASA of a potential second observation of plume activity on Europa, is there a push to alter the scientific goal of the NASA Europa Clipper mission to include life detection? How would such a decision be made? Is it possible to add life detection instruments to the spacecraft at this point in its development?

5. Last month, NASA announced that Cassini composition measurements revealed the presence of molecular hydrogen in the plume material spewing from the surface of Enceladus, thus providing an "independent line of evidence that hydrothermal activity is taking place in the Enceladus ocean." As you know, hydrothermal activity provides a necessary chemical energy source for life. What future verification and confirmation activities will logically flow from discoveries such as this and how can excitement be sustained until those activities can be undertaken?

6. What is the status of the NASA Nexus for Exoplanet System Science (NExSS) initiative? What results have come from the initiative and what plans does NASA have for NExSS over the coming years?

7. What is the status of NASA's plans for a future mission to return cached samples collected by the Mars 2020 rover so they can be studied by researchers on Earth? You mention in your statement that NASA is "exploring opportunities to partner with industry to leverage their future missions to advance decadal survey science objectives." Can you expand on that? When can we expect to get more details on when and how cached samples from Mars will be returned to Earth?

8. How do scientific and technological advances in astrobiology impact the way NASA sets its broader astrophysics science goals? In your view, are any changes to this process needed?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

September 13, 2017

Reply to Attn of: OLIA/2017-00241f:SWQ

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Babin:

Enclosed is material for the record and responses to written questions submitted by Ranking Member Bera, Ranking Member Johnson and Representative Lofgren resulting from the June 8, 2017, hearing at which Acting Administrator Robert Lightfoot testified regarding "An Overview of the Budget Proposal for the National Aeronautics and Space Administration for Fiscal Year 2018."

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

cc: Ranking Member Bera

Enclosure

Material requested for the record on page 77, line 1826, by Representative Rohrabacher during the June 8, 2017, hearing at which Administrator Robert Lightfoot testified.

NASA is focused on completing Space Launch System (SLS) development, producing the first SLS flight articles, and ensuring a sustained cadence of exploration missions that will ensure continued U.S. leadership in deep space exploration through the 2020s and beyond. Although it is premature to provide a detailed cost for an SLS launch at this stage in the program's life cycle, NASA's preliminary estimate for the marginal cost of an SLS launch early in the program's production and operations phase, is on the order of $0.7 - 1.0 billion, which represents the cost of a second SLS in a given year where the fixed costs are covered by the first SLS launch. This preliminary estimate of the marginal cost includes the SLS core stage, boosters, and Exploration Upper Stage, but does not include Orion and/or cargo elements, or enterprise/ground operations and integration costs. NASA has assessed the results from a recent affordability Request for Information (RFI) and will work with industry to reduce overall costs once SLS and ground systems enter the production and operations phase.

Material requested for the record on page 78, line 1847 and 1854, by Representative Rohrabacher during the June 8, 2017, hearing at which Administrator Robert Lightfoot testified.

Orbital debris mitigation remains an important effort internationally given the ever increasing number of countries and other entities developing space capabilities. The U.S. continues to adhere to and seek international implementation of space debris mitigation measures through national policies, laws, and regulations, as well as research into new capabilities for better characterization of the space debris populations and new technologies that might ultimately remove space debris from orbit. More specifically, in United Nations meetings and other international fora, the United States continues to encourage international adherence to the Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines and the guidelines developed by the Committee on the Peaceful Uses of Outer Space (COPUOS) of the United Nations, which were endorsed by United Nations General Assembly in 2007, as vital in the effort to control the space debris problem for the safety of future space missions. In addition, NASA is participating in a new activity to improve the IADC Space Debris Mitigation Guidelines. This effort aims to quantify several elements in the guidelines, including the 25-year post mission decay rule for LEO spacecraft and upper stages, the 1 in 10,000 random reentry human casualty risk threshold, the 0.001 probability limit for accidental explosions during mission operations, and the 0.9 reliability threshold for post-mission disposal operations. The activity is expected to be completed with updates to the IADC Space Debris Mitigation Guidelines in 2018.

While it is under study, active removal of orbital debris removal has far reaching technical, legal, and economic implications. The remediation of the near-Earth space environment will necessarily involve an international effort. Since international treaties prevent a country from removing space objects that do not belong to it, the United States, by itself, cannot solve the orbital debris problem. NASA works with our international partners through the Inter-Agency Space Debris Coordination Committee (IADC) and the Committee on Peaceful Uses of the Outer Space of the United Nations (UN COPUOS). The IADC has an on-going study to quantify the benefits of active debris removal but the study will not be concluded before 2019. The UN COPUOS is developing a set of guidelines for the Long-Term Sustainability of Outer Space Activities (LTS).

There have been some international meetings focusing on active debris removal in recent years, but they have focused on concept and technology development rather than international coordination for ADR operations. Example of such meetings include the following:

- NASA and DARPA co-organized the first-of-its-kind "International Conference on Orbital Debris Removal" in Chantilly, VA, in 2009. The conference was well attended by approximately 280 participants from 9 foreign countries and the United States. More than 50 presentations were grouped into 10 sessions ranging from defining the problems, to small and large debris removal, and to the legal and economic issues for removal operations.

- The French Space Agency, CNES, has organized a bi-annual "European Workshop on Active Debris Removal" since 2010. It was renamed "European Workshop on Space Debris Modeling and Remediation" in 2014. The event regularly attracts about 150 technical experts for presentations on various technology development, testing, and feasibility studies. NASA provided keynotes at several workshops.

The orbital debris problem is creating a major challenge for space situational awareness (SSA) and for the safe operation of U.S. space assets. NASA is taking a number of steps to address this challenge, and will continue to work to better define the orbital debris population for near-term debris impact risk assessments, protect critical space assets, evaluate the far-term sustainability of the environment, and initiate early technology development to reduce the risk in the future.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2018"

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

Question submitted by Rep. Zoe Lofgren,
House Committee on Science, Space, and Technology

As you know, I'm fortunate enough to have a NASA Center, NASA Ames, near my district in California, and many of my constituents who live in San Jose work there. The research being done at NASA Ames fits well in to the Silicon Valley personality- it's innovative and cutting edge.

One of those programs is the Stratospheric Observatory for Infrared Astronomy (SOFIA), the world's largest airborne observatory. The aircraft is based at the Armstrong Flight Research Center in Palmdale and the science and mission operations are based at NASA Ames.

The airplane-based telescope has supported astronomical research that cannot be done in other ways, providing a unique vantage on our solar system, galaxy and the history of the Universe. SOFIA was built and planned to be operated as a partnership with the German Space Agency. It also provides a unique educational platform, including K-12 science teachers on research flights, with the professional astronomers and technicians.

Yet, the funding for SOFIA ramp down after the senior review in 2019. This seems to set up a contentious situation where SOFIA will have to take funding from other programs.

QUESTION 1a:

If SOFIA has a successful senior review, from where will the money be restored?

ANSWER 1a:

A funding line for a SOFIA extended mission is held under "Cosmic Origins Future Missions," however, the outyear budgets are notional. SOFIA's budget will be determined as part of the FY 2020 initial operating plan following the 2019 Senior Review.

QUESTION 1b:

Is ramp down in funding two years before a planned senior review consistent with how other projects of similar size have been treated?

ANSWER 1b:

With the reduction in jet fuel prices over the past years, and SOFIA's increasing efficiencies in operations, SOFIA has accumulated uncosted carry over. In other words, they are spending less than their appropriated budget. By reducing the SOFIA budget slightly in FY 2018 and FY 2019, it is expected that the SOFIA project will burn down the uncosted carryover with no impact to science or operations.

NASA is continuing to maintain and update SOFIA's capabilities so that SOFIA is capable of operating should the Senior Review conclude that it continues to be scientifically productive relative to its cost. NASA and our German partners are developing a suite of state-of-the-art instruments that provide an order-of-magnitude more science capability than the original suite of instruments that was selected 20 years ago. For example, NASA has developed the High-Resolution Airborne Wideband Camera-plus (HAWC+), which recently began operations on SOFIA. Our German partners have developed the Upgraded German Receiver for Astronomy at Terahertz Frequencies (upGREAT), which is currently available to SOFIA users. NASA has begun development of the High-Resolution Mid-Infrared Spectrometer (HIRMES), which will begin operations on SOFIA in 2019, and we will be soliciting proposals in 2018 for a fourth-generation instrument to be developed for use on SOFIA after that. The recently built fuel farm at the Armstrong Aircraft Operations Facility provides the necessary infrastructure to safely support SOFIA refueling. We continue to acquire and steward the spare aircraft parts and experienced personnel necessary to maintain SOFIA's operational capability.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2018"

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

QUESTION 1:

NASA has a unique and important role when it comes to inspiring our nation's next generation of scientists and engineers. That is why I am very troubled that the President's FY 2018 budget request proposes to eliminate NASA's Office of Education.

QUESTION 1a:

What is the justification for this decision?

ANSWER 1a:

The Office of Education has experienced significant challenges in implementing a focused NASA-wide education strategy. Additionally, the Office of Education lacks sufficient outcome measures to assess the effectiveness of its programs. During this time of fiscal constraint, the federal government is eliminating programs that have not demonstrated effectiveness. NASA's mission content will continue to inspire the next generation through the many ways that our work excites and encourages discovery by learners and educators.

QUESTION 1b:

What is the rationale for eliminating the Office rather than addressing any management issues that have been identified?

ANSWER 1b:

The agency is addressing these and other concerns at this time. An agency-wide approach to Education and Outreach is in work as part of NASA's Education & Outreach Business Services Assessment (BSA). Although this assessment began prior to the Administration's proposal to eliminate the Office of Education, the results of this process enables the agency to increase efficiency and optimize the synergies between STEM engagement and outreach activities that expose our Nation's learners to NASA's unique missions.

QUESTION 1c:

How does the potential elimination of the Office impact on NASA's role of fostering the recruitment and retention of our Nation's next generation of scientists and engineers?

ANSWER 1c:

NASA will continue to inspire the next generation through its missions and the many ways that our work excites and encourages discovery by learners and educators. Internships, fellowships, and outreach activities funded outside the Office of Education are planned to continue. While the percentage may vary from year to year, on average nearly 70 percent of internships at NASA field centers are funded outside of the Office of Education, and will continue even without a traditional Office of Education. The Science Mission Directorate (SMD) STEM Science Activation program will continue to focus on delivering SMD content to learners of all ages through cooperative agreement awards.

QUESTION 2:

The budget proposal does not include funding for Space Grant, EPSCoR, or MUREP, contrary to longstanding Congressional support for these programs. What is the specific justification for eliminating these programs?

ANSWER 2:

While NASA has long tracked output data (e.g., number of people funded, number of papers generated, number of events supported) for these projects, outcome-related data demonstrating program effectiveness has been insufficient to fully assess their impact. NASA believes that STEM engagement efforts, currently undertaken by mission directorates and other functional offices, will provide opportunities for learners to participate in STEM engagement activities that capitalize on NASA-unique assets and content.

QUESTION 3:

I understand that the Wide Field Infrared Survey Telescope (WFIRST) is nearing its System Requirements Review. I am encouraged to hear that NASA is taking feedback from the National Academies to heart and will be conducting an independent technical, management, and cost review of the mission prior to the System Requirements Review and the start of development. What other lessons NASA has learned from JWST and how you will apply those lessons to the development of WFIRST and future large scale missions?

ANSWER 3:

The root causes of the James Webb Space Telescope overrun were an initial budget estimate that was too low; growth in capabilities and complexity; and reserves that were skewed to the outyears providing inadequate resources in the early years when technical challenges arose. To ensure an accurate budget estimate, the WFIRST team has acquired seven independent cost estimates over the past six years which validated NASA's estimates for cost, schedule, and risk each time. Now that the project is in formulation, NASA has initiated an independent, external review over the next several months on the scope of the WFIRST project to help ensure it would provide compelling scientific capability with an appropriate, affordable cost and a reliable schedule. NASA intends to incorporate these recommendations into its design and plans for WFIRST before proceeding with development of the mission. A similar independent review was conducted during the development of Webb, but much later in the development cycle. To provide management insight into the project's performance against commitments, we are utilizing earned value management tools, tracking technical, schedule, and cost metrics during each monthly review. Finally, the WFIRST design incorporates only two new technologies, both of which have completed laboratory demonstrations one full year prior to the date required by NASA standards; one of the new technologies, the coronagraph instrument, is classified as a "technology demonstration," i.e., its performance does not affect our overall mission success criteria. This reduces the technical risk of the WFIRST mission compared to Webb.

QUESTION 4:

Most experts agree that the most significant factor preventing the achievement of the full potential of unmanned aircraft systems is the need to ensure that all vehicles flying in the National Airspace System (NAS) can do so safely.

QUESTION 4a:

What is the status of NASA's collaborative efforts with FAA to safely integrate UAS into the NAS?

ANSWER 4a:

NASA is working closely with the FAA to understand barriers to integration of UAS into the National Air Space (NAS), to prioritize and address those barriers where NASA has unique expertise and to effectively transition research findings to appropriate offices in the FAA. NASA has provided research results from simulations and flight test that have been used to define Minimum Operational Performance Standards for Command and Control and Detect and Avoid functions for an unmanned aircraft transiting Class E and G airspace, in route to operations in Class A airspace. NASA is currently planning research activities to provide similar research findings for a mission that includes sustained operations in Class E Airspace. This is a significantly more challenging mission for UAS.

NASA also is collaborating with the FAA to explore the technical challenges that must be addressed to safely enable operations of small UAS at low altitudes through the UAS Traffic Management (UTM) project. UTM is a research platform that is intended to enable safe airspace operations for all operators by providing common picture of the airspace, allows for exchange of information among aircraft and operators as well as with FAA's Air Traffic Management systems. NASA is working closely with FAA, other federal agencies and industry to develop and validate airspace operations, functions, roles and responsibilities, and integration requirements associated with UTM.

NASA participates in multiple FAA-organized forums to solicit the unfiltered "voice" of industry on UAS issues, with NASA experts currently serving on the ID and Tracking Aviation Rulemaking Committee as well as the FAA's Drone Advisory Committee. NASA is active in discussion of UAS integration policy issues through the U.S. Government UAS Executive Committee and its attendant Senior Steering Group. In addition, NASA is working closely with the FAA chartered test sites and using their unique capabilities to augment NASA research capabilities.

FAA and NASA have formed two UAS-related Research Transition Teams (RTT) to ensure that NASA research outcomes provide valuable information to the FAA for their decision making related to UAS operations. FAA provides subject matter expertise to NASA through the RTTs to ensure high relevancy of NASA's research. One RTT is focused on UTM concepts and requirements for data exchange and information architecture, communication and navigation and detect/sense and avoid. Through the RTT, NASA and FAA are developing a comprehensive concept of operations starting from NASA's original UTM concept, data exchanges among airspace users, information architecture, sense and avoid, and performance technologies. The UTM RTT will culminate into key technical transfers of concepts and technologies to FAA, as well as a joint

UTM pilot program plan.

A second FAA-NASA RTT is focused on issues associated with integrating larger (greater than 55 lbs), higher performance UAS into the NAS. Working Groups have been established to address Detect and Avoid, Command and Control, Operations and Advanced Concepts and a No Chase Certificate of Authorization (COA).

All of these efforts have resulted in increased efficacy of NASA's research related to UAS integration and effective use of resources to address policy and rulemaking associated with routine UAS integration into the Nation Airspace System.

QUESTION 4b:

What impact would privatizing FAA's air traffic control system have on such collaborative efforts?

ANSWER 4b:

NASA does not anticipate that privatizing the FAA's air traffic control function would have a substantial impact on our collaboration with the FAA as it relates to UAS integration. NASA will continue to research concepts and technologies related to safe integration of UAS into the national air space, and transition them to the appropriate entities in the FAA and/or a newly privatized operational organization. NASA has extensive experience working with and transitioning technologies to government and private sector civil aviation organizations and companies. NASA has used active air traffic controllers in our research in the past and we would anticipate still having access to the cadre of active air traffic controllers to increase the validity of our research findings.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2018" Mr. Robert M. Lightfoot, Jr., Acting Administrator, National Aeronautics and Space Administration (NASA)

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

QUESTION 1:

During the hearing, you testified that NASA is planning to have a habitat operating in cislunar space by the mid-2020s. What are the milestones that need to be met in order to have a cislunar habitat by the mid-2020s? Does the 5-year budget plan support such a development schedule, or will inflationary growth, at a minimum, be needed in the human exploration budget?

ANSWER 1:

NASA is engaged with several commercial and international partners to advance and test a variety of habitation technologies and infrastructure options. The Next Space Technologies for Exploration Partnerships (NextSTEP) activity, plus related technology developments and partnerships, will enable deployment of an initial deep space habitation capability in the mid-2020s. The purpose of the NextSTEP Habitation development activity is to investigate leveraging U.S. industry capabilities that could enable NASA habitation needs from LEO commercialization activities all the way through development and testing of a Mars-class habitation system.

Currently in Phase 2 of this effort, NASA is developing habitation system concepts and technologies from six U.S. companies (Bigelow Aerospace, Boeing, Lockheed Martin, NanoRacks, Orbital ATK, Sierra Nevada Corp.) with the goal of developing full-size cislunar habitat ground prototypes by 2018. These ground prototypes will allow NASA and the NextSTEP habitation partners to: 1) evaluate configurations and habitability attributes of the habitat, 2) assess how the various systems interact together and with other capabilities like propulsion modules and airlocks, and 3) provide platforms to test and ensure that the standards and common interfaces being considered are comprehensive and enable the intended interoperability. Each of these activities will contribute to validating the systems needed for more challenging human future deep space activities.

Concurrently, NASA is assessing opportunities for international collaboration in developing cislunar habitation capabilities, including through leveraging current ISS and other partnerships.

The initial cislunar habitation capability can be configured differently depending on mission needs and though there are various concepts for configuration, current analysis has concluded that this habitation capability is composed of four functional capabilities: habitat, logistics module(s), airlock, and a power/propulsion bus. Progressing the commercial NextSTEP-2 activity, continuing with technology development, and continuing discussions with potential international partners will all contribute to decision(s) on an acquisition approach for habitation for deep space and for commercial investment in LEO capability.

At this time, a cislunar "Gateway" is only a concept, and the activities described above, along with other considerations, will help inform whether NASA will pursue it in the 2020s. To support an operational cislunar Gateway in the mid-2020s, major milestones include the identification of functional allocations and requirements, the Gateway acquisition strategy (mid-2019), and Gateway elements delivered to Kennedy Space Center nine months prior to launch. Because development of the elements would be spread over several years, the funding estimates indicate that the President's FY 2018 Budget Request is supportive of these efforts. Whether there are additional needs to support a the concept by the mid 2020s is still being assessed, along with NASA's plans to pursue it moving forward.

For further information on NextSTEP, please access the following website:

https://www.nasa.gov/nextstep

QUESTION 2a:

Under the Commercial Crew program, two U.S. companies are developing spacecraft to carry astronauts to and from the International Space Station (ISS). Under current plans, both providers are expected to complete certification of their systems during 2018. However, delays in the program led the GAO to recommend that NASA develop contingency plans in case the companies are not ready to launch U.S. astronauts.

a: What is the confidence level that current planned dates for certification will be met by the Commercial Crew providers, and what are the factors most likely to disrupt this schedule?

ANSWER 2a:

In general, recent delays associated with the partners' commercial crew contract schedules reflect normal development difficulties and technical challenges associated with human space transportation systems. The Commercial Crew Program is currently tracking specific technical and programmatic risks that could result in additional schedule delays. Two top programmatic risks are: difficulty in meeting the loss of crew requirement and aborting into sea states with unsafe rescue. Specific technical issues associated with the partner designs are proprietary, but non-proprietary status updates are provided at public meetings of the NASA Advisory Council

(NAC) and NAC HEO Committee.

QUESTION 2b:

What are the most difficult challenges that remain prior to successful certification?

ANSWER 2b:

As noted above, recent delays associated with CCP contract schedules reflect normal development difficulties and technical challenges associated with human space transportation systems as our partners prepare to meet certification reviews and other milestones.

QUESTION 3a:

The FY 2018 budget provides support for a new Science Mission Directorate initiative that seeks to leverage small satellites to address some of NASA's high-priority science objectives.

> a: How does NASA plan to coordinate smallsat activities across the different Science divisions?

ANSWER 3a:

NASA is formalizing a new Small Spacecraft Coordination Working Group (SSCWG), with membership from SMD, STMD, and HEO, to enhance coordination for all NASA small spacecraft activities. The SSCWG will identify high-priority science objectives, across Science Divisions and Mission Directorates, which can be addressed with CubeSats/SmallSats and conduct a strategic assessment to identify technology gaps and opportunities. This collaborative team will allow the divisions and directorates to expand capabilities with strategic investments while avoiding unnecessary duplication. SMD will also continue encouraging the miniaturization of instruments through its solicitation process, as it does now in projects across all four Science Divisions.

QUESTION 3b:

Does NASA plan to partner with the commercial sector on this initiative? If so, how?

ANSWER 3b:

SMD and STMD are actively engaged in pre-planning activities to establish new programs that would enable the use of public-private partnerships for these missions and will continue to work with our partners to take advantage of secondary/hosted payload opportunities on commercial launches. NASA intends to leverage and partner with the growing commercial sector to collaboratively drive instrument and sensor innovation. Given the pace at which these technologies are changing, we will have more frequent engagements with industry and the scientific community to gain insight and understanding into new and/or enhanced capabilities.

QUESTION 4:

The FY 2018 budget request provides no funding for a Europa lander mission, despite legislative language in the FY 2017 Consolidated Appropriations Act directing NASA to launch a lander mission by 2024. What was NASA's rationale for not requesting funding for a Europa lander in this budget?

a: If NASA doesn't believe that 2024 is the optimal timeframe for a lander mission to Europa, what is NASA's preferred time table for such a mission and why?

ANSWER 4-4a:

NASA's Planetary Science portfolio currently supports two large strategic missions in the five-year budget horizon (Mars 2020 and Europa Clipper); thus, the Europa Lander mission was not included in the FY 2018 President's budget request since it could not be accommodated without significant impacts to other programs. Additionally, a Europa lander was not in the last planetary Decadal Survey conducted by the National Academies.

Beginning design and development work on a lander before the science community is able to evaluate data from the Europa Clipper mission may impact the science return from a future lander mission.

QUESTION 5a:

NASA expects there to be several missions operating on Mars in the early 2020s. The Mars Reconnaissance Orbiter, which provides the vast majority of the data relay between surface vehicles and Earth, will have been operating for 15 years by then.

a: How does NASA plan to meet the increasing Mars-Eruth telecommunications needs?

ANSWER 5a:

NASA's Deep Space Network (DSN), which has been in operation for over 50 years, provides communication and tracking services to about 35 NASA and non-NASA missions beyond geosynchronous orbit (26,000 miles above the Earth's surface). Its three deep space communication complexes, all of which are owned by NASA, are located in Goldstone, California; Canberra, Australia; and Madrid, Spain. The sites are separated by approximately 120 degrees of longitude to ensure that any spacecraft in deep space can communicate with at least one station at all times as the Earth rotates. The Space Communications and Navigation (SCaN) Program actively seeks to implement operational efficiencies to help fund modernization and upgrade activities.

Realizing the need for additional capacity in the early 2020s, SCaN has been actively working to modernize and upgrade the DSN capabilities in addition to securing cross support agreements with other space agencies. SCaN established the DSN Aperture Enhancement Project (DAEP) to modernize and upgrade the DSN's ground stations, and to enhance capacity, improve flexibility to support customer missions, and reduce operations and maintenance costs. To date, SCaN has added two new 34-meter antennas at the Canberra, Australia facility and is actively working to build and bring online two additional antennas in Madrid, Spain. The new 34-meter antennas are easier and more cost-effective to maintain, in addition to providing the same or better performance as the 70-meter antennas when arrayed. In addition to cross-support agreements completed or in work with other space agencies, SCaN is working with the Italian Space Agency to use their Sardinia 64-meter antenna as a backup capability. Moreover, SCaN is presently working on adding capabilities to the existing antennas to support up to four users' co-located missions per antenna. SCaN is maintaining an effective operation and maintenance effort, leveraging efficiency to increase productivity and reliability.

SCaN is working closely with the Science Mission Directorate's Mars Program to address future requirements, and is conducting studies to identify future space-based relay communication and navigation architectures for Earth and Mars that are infused with technologies under development to support NASA missions in the 2022 and beyond timeframe. Evolving space communication systems will transform future NASA mission capabilities. SCaN's technology development effort invests in leading-edge communications technologies, and enables, improves, and matures available spacecraft communication and navigation technologies to build capabilities for both ground and space-based use. Some of the technologies that SCaN is currently working on are optical communication and software-defined radios.

QUESTION 5b:

What is the confidence level that NASA's current plans will avoid a gap in telecommunications between Mars and Earth? What would the consequences of a telecommunications gap be?

ANSWER 5b:

As noted in the response to Question #5a, SCaN is actively working to modernize and upgrade the DSN and we do not anticipate a gap in telecommunications between Mars and Earth. The DAEP modernizes and upgrades the DSN's ground stations to enhance capacity, improve flexibility to support customer missions, and reduce operations and maintenance costs. Without continuing maintenance and repair work, the Agency would be at risk of losing valuable data as the existing antennas required significant repair work.

QUESTION 6:

NASA, in its FY 2018 request, proposes to try to leverage NASA and DOD initiatives in hypersonics. Please provide details on how NASA will apply its expertise in hypersonics and unique test facilities to complement DOD's efforts. In what areas, if any, will civil aviation benefit from such research?

ANSWER 6:

NASA is focused on developing the next generation of hypersonic capabilities. These capabilities have the potential to support both military and civil applications in the future. By coordinating closely with the DoD, NASA can leverage extensive DoD ground and flight test opportunities to provide data and insight that helps support NASA research. For example, experimental data can be compared to the results of computer simulations, which helps validate NASA's computational capabilities. At the same time, by working closely with the DoD, NASA is able to provide technical support and complementary research that enhances the DoD projects and also reduces technical risk. Therefore, NASA can focus on generating tools and technologies for the next generation of hypersonic applications while having a direct benefit to current DoD efforts.

NASA has worked with the DoD to identify the suite of test facilities that are most critical for developing new hypersonic capabilities. A number of these facilities are owned and operated by NASA, and some are used by the DoD to generate ground test data. In addition, NASA coordinates with the DoD to ensure that accompanying test technologies and knowledge about conducting hypersonic testing are shared. NASA is also cooperating with the DoD in more foundational research and developing the next generation technical workforce. In particular, NASA is well-coordinated with the Air Force Office of Scientific Research and supports research with the university community.

While the first applications of hypersonic technologies will be for military missions, there is a potential for future civil applications. Access to space is one such civil mission that may be enhanced through air-breathing hypersonics. Some companies are also exploring hypersonic civil transports such as Boeing's recent announcement that it is considering hypersonic civil transport as a future technology. Research on specific hypersonic tools and technologies can also be leveraged for other aircraft applications. An example is the development of high temperature materials for turbine engine components that was enabled by the NASA research on high temperature materials for hypersonic applications.

QUESTION 7:

The in-space robotic servicing initiative known as Restore-L was appropriated $130M in the FY 2017. The FY 2018 budget request would terminate that mission and, according to the accompanying budget justification, *"will transition the Restore-L project to reduce its cost and support a nascent commercial satellite servicing industry"*, further adding that *"NASA is pursuing a potential collaboration with the Defense Advanced Research Projects Agency (DARPA) and with industry to most effectively advance satellite servicing technologies and* *ensure broad commercial application."*

QUESTION 7a:

Can you talk about the similarities and differences of both activities?

ANSWER 7a:

The comparison of NASA's Restore-L project to DARPA's RSGS project are provided in the attached table: (SEE ATTACHED TABLE)

QUESTION 7b:

In light of the direction in the FY 2017 appropriations, will satellite servicing development activities currently conducted by NASA continue in FY 2017 at the level appropriated or is NASA planning to reduce the scope of its activities in consonance with its proposed termination of Restore-L?

ANSWER 7b:

For FY 2017, NASA is continuing technology development for the Restore-L satellite servicing project as directed in the Consolidated Appropriations Act of 2017.

QUESTION 7c:

What is the status of NASA's discussions with DARPA on a collaborative effort?

ANSWER 7c:

NASA and DARPA have agreed to a set of goals and principles for a DARPA/NASA collaboration on Satellite Servicing. These include meeting both organizations' goals for advancing satellite servicing capabilities and technologies and transferring those to industry to enable commercial services; accelerating the mission timeline, reducing risk, or increasing the probability of success via resource utilization of all organizations involved; conducting a demonstration in the appropriate orbit that best accomplishes the goals of both organizations; and assuring that technologies and capabilities are transferred broadly to U.S. organizations to support commercial activities. Discussions have been occurring at the project level between both organizations to identify options for collaboration.

QUESTION 7d:

How will NASA *"effectively advance satellite servicing technologies and ensure broad commercial application"?*

ANSWER 7d:

NASA's In-space Robotic Servicing/Restore-L project has developed an extensive, written technology transfer plan of which its guiding principles are to provide a level playing field, to share data and information during the various stages of the project, and to foster a constant, iterative dialogue along the way. In August 2016, NASA issued a public synopsis of its Restore-L plan which provided background on the project, introduced the objectives of testing crosscutting satellite servicing technologies, stated the plan to transfer technologies to U.S. commercial entities to help jump start a commercial on-orbit robotic satellite servicing capability, and solicited interest and feedback on this plan. In April 2017, NASA held its first in a series of day long industry workshops on In-Space Robotic Servicing/Restore-L to present information on technology development to date and will continue periodically conducting these workshops through 2019. Ongoing activities include responding to inquiries, continued dialogue as requested, and controlled access to facilities to help industry obtain the information they need to advance their business plans for a commercial satellite servicing industry.

QUESTION 8:

The FY 2018 budget makes clear that leveraging public-private partnerships is a priority for NASA, but offers few details on how these partnerships will be used. Can you provide specifics on any new public-private partnerships being planned for FY 2018? Will there be any changes to the way NASA conducts its partnerships?

ANSWER 8:

NASA regularly partners with U.S. industry and other private sector partners. Such partnerships are instrumental in supporting the Agency's strategic plan and Agency objectives, including expanding human knowledge; advancing U.S. competitiveness; disseminating the results of NASA's activities to educate and inspire; and facilitating the efficient use and management of Agency infrastructure and capabilities. Currently, NASA has about 1,200 active partnerships with U.S. industry and other private sector entities. By supporting the development and utilization of new knowledge and technologies by its domestic partners, NASA helps improve America's industrial supply chain, maximizes the U.S. taxpayers' return from their investment in NASA research and development, and leverages private sector approaches to develop and commercialize technology.

NASA employs several kinds of commercial partnership mechanisms to address U.S. space capabilities, including – but not limited to – Federal Acquisition Regulation (FAR)-based contracts to fulfill Agency requirements, as well as funded and unfunded Space Act Agreements (SAAs), which support and encourage commercial innovation. The Commercial Resupply Service (CRS) contracts, under which Space Exploration Technologies (SpaceX) and Orbital ATK have been providing cargo resupply to the International Space Station (ISS), are examples of the former. NASA's Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) initiative, which has established multiple no-funds-exchanged SAA partnerships

with U.S. private sector entities, is an example of the latter.
NASA will continue to actively engage U.S. private sector partners in FY 2018 and beyond. Some examples of planned partnerships include the following:

A nonreimbursable (no exchange of funds) collaboration with a U.S. university to develop and test water and solid waste treatment technologies.

A reimbursable arrangement (wherein the partner reimburses NASA for its costs) with a consortium of U.S. companies to develop infrared (IR) technology and to advance the general state of the art in infrared detectors to enable commercial production of such detectors for supply to U.S. government and commercial customers.

A reimbursable arrangement with a U.S. company to provide support and advice for commercializing space-based optical communications technology and improve upon the speed of the optical data communication.

A reimbursable arrangement with a U.S company to provide an objective, non-industry assessment of a unique, but broad, class of printed wiring boards produced in the supply chain for the purpose of developing a risk based protocol to insure the integrity and flightworthiness of industry printed wired boards (PWBs).

A reimbursable arrangement with a U.S. university to provide NASA optical communications expertise to assist testing and modeling of atmospheric effects on laser propagation at several elevations.

A nonreimbursable collaboration with a U.S. university to facilitate development of nano-satellite sub-systems and sensors.

NASA has been very effective in its utilization of partnerships with private sector partners and does not currently anticipate significant changes in the way the Agency conducts its partnerships function; however the Agency is continuously seeking to enhance its effectiveness in engaging U.S. private sector partners for mutual benefit.

Comparison of Restore-L and RSGS

	Restore-L	RSGS
Goals/Mission	1. Demonstrate satellite servicing capabilities in LEO 2. Advance essential technologies for NASA and National goals 3. Kick-start a new U.S. commercial servicing industry	1. Demonstrate in or near GEO that a robotic servicing vehicle can perform safe, reliable, useful and efficient operations, with the flexibility to adapt to a variety of on-orbit missions and conditions 2. Demonstrate satellite servicing mission operations on operational GEO satellites in collaboration with commercial and U.S. Government spacecraft operators 3. Support the development of a servicer spacecraft with sufficient propellant and payload robustness to enable dozens of missions over several years
Capabilities Enabled	1. Remote inspection 2. Repair 3. Relocation 4. Rendezvous, Capture 5. Upgrade installation 6. Refueling	1. Remote inspection 2. Repair ("anomaly correction") 3. Relocation 4. Rendezvous, Capture 5. Upgrade installation *Note: Although refueling is not a requirement of RSGS, it is anticipated that DARPA's industry partner will be including this capability.

Technologies	• Relative Navigation Sensors and Algorithms • Advanced Avionics • Servicing Robotics • Servicing Tools • Propellant Transfer • Mission Autonomy Manager • Berthing System • Vision System	• Sensors to provide spatial orientation • On-board mission planning software • Servicing Robotics • Servicing Tools • Supervised Autonomous Robotic Operations • Advanced Algorithms for Machine Vision
Major Participants	• Goddard Space Flight Center – Servicing Payload Development • Kennedy Space Center – Propellant Transfer System • Space Systems Loral – Spacecraft Development	• Naval Research Lab – Servicing Payload Development • Space Systems Loral – Industry Partner and Spacecraft Development
Launch Date	• 3rd Quarter FY2020	• 2nd Quarter FY2021
Technology Transfer Plan	• Technology to be shared with all interested domestic entities during development stages (in parallel) and after mission completion	• Technology to be shared with all interested domestic entities after mission completion

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

September 1, 2017

Reply to Attn of: OLIA/2017-00268f:SWQ

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Ranking Member Bera and Representative Knight resulting from the June 29, 2017, hearing at which Mr. William Gerstenmaier and Mr. Stephen Jurczyk testified regarding "In-Space Propulsion: Strategic Choices and Options."

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

cc: Ranking Member Ami Bera

Enclosures

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"In-Space Propulsion: Strategic Choices and Options"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, National Aeronautics and Space Administration (NASA)

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

QUESTION 1a:

The National Academies' Pathways in Exploration report identified cryogenic propulsion, Nuclear Electric Propulsion, Nuclear Thermal Propulsion, and Solar Electric Propulsion as propulsion technologies "of greatest interest." The report added that *"As the technologies for in-space propulsion are developed and matured, there will likely need to be a down-selection among the four options due to the high development costs required for each one."*

a. Do you agree that avoiding the high development costs associated with maturing propulsion technology options could be achieved by moving to a down-selection acquisition strategy?

ANSWER 1a:

In undertaking public-private partnerships, such as the Next Space Technologies for Exploration Partnerships (NextSTEP) effort, NASA's strategy is to avoid high development costs associated with maturing propulsion (and other) technology options. NASA, along with private sector partners, is developing solar-electric propulsion (SEP) capable of positioning future habitats, landers, and other elements in Mars orbit, and possibly deliver crew to Mars on a hybrid vehicle that also uses storable chemical propulsion.

NASA is continuing to develop advanced Hall-effect electric thruster and propulsion technologies that could be used for the Deep Space Gateway concept, and are extensible to deeper space missions. NASA intends to examine, as part of NextSTEP, commercial spacecraft concepts at this power level as the initial element in a gateway as well as a future U.S. capability. As part of the NextSTEP effort, NASA is also evaluating higher-power electric propulsion technologies that offer the potential for substantially reduced transit times to Mars and other deep space destinations. These higher power technologies are in the early development stage, with several significant system development challenges that need to be addressed prior to being incorporated in an acquisition strategy and implemented on a NASA mission. Partners will demonstrate electric propulsion systems with higher specific impulse, higher efficiency, and higher power for long-duration deep space transportation systems and look at capabilities that are beyond those previously considered.

Cryogenic propulsion would be used primarily for mission phases that require high thrust, such as ascent from the surface of Mars. NASA does not currently expect to require nuclear thermal propulsion (NTP) or nuclear electric propulsion (NEP) in the initial crewed missions to the Mars system. Other advanced propulsion technologies, such as high-powered SEP combined with chemical systems, meet the needs of U.S. commercial aerospace industry while serving as the core capabilities for the initial in-space propulsion system for the Mars crewed missions.

QUESTION 1b:

If you do, how could such a down-selection be structured?

ANSWER 1b:

NASA's concept plans are to develop both a cislunar habitation capability and a Mars transit capability during the decade of the 2020s. To support estimated technology maturation and system development schedules for the transit vehicle, a downselect decision point would be targeted in 2020.

QUESTION 1c:

If you do not agree, how would you proceed and what would be the cost implications?

ANSWER 1c:

Please see response to Question #1b, above.

QUESTION 2:

What are the key decision points for making commitments on in-space propulsion technologies? What has NASA learned about how to consider trade-offs among the technology options? To what extent are trade-offs dependent on the details of a mission? To what extent will the amount of time that crews are exposed to radiation influence NASA's decision on which technologies to pursue?

ANSWER 2:

NASA's concept includes the development of a cislunar habitation capability and a Mars transit capability during the decade of the 2020s. To support estimated technology maturation and system development schedules for the transit vehicle, a downselect decision point is targeted in 2020. The results of NextSTEP concept developments using higher-power thruster technologies and the STMD nuclear thermal propulsion risk reduction activities will inform the design for the propulsion system of the Mars transit vehicle. By the end of the 2020s, this work will culminate in a one-year validation mission or "shakedown cruise" of astronauts aboard the transit vehicle that will verify that the propulsion system – as well as environmental control and life support systems – is ready for an interplanetary mission.

Mission design is a critical influence on trade-offs among technology options. In the area of propulsion, for example, chemical rockets provide high initial thrust and rapid acceleration, but are not very efficient, and cannot carry the fuel required to thrust continuously over interplanetary distances. Solar electric propulsion, in contrast, provides a low-thrust, but very efficient system which can operate for much longer periods of time, building up speed more slowly, but to a potentially higher final speed. Consideration of crew exposure to radiation will inform NASA's decisions about propulsion systems for crewed vehicles, possibly resulting in a hybrid chemical/SEP system that benefits from the advantages of both technologies.

QUESTION 3a:

Some space experts have advocated for using telepresence, where scientifically skilled humans work hand in hand from orbit with surface robots. These experts contend that more exploration could be conducted if it was not limited by astronauts operating on foot. In addition, by not landing on places like Mars, there would be less of a chance of introducing terrestrial contamination. The Gateway concept you introduced in March seems to provide opportunities for telepresence in exploration.

a: What are the pros and cons of telepresence in NASA's human exploration strategy?

ANSWER 3a:

NASA considers telepresence to be an important element of human space exploration. One example of this in low-Earth orbit is the extensive use of remote manipulators ("robotic arms"), in addition to astronauts conducting extravehicular activities (EVAs), first to assemble, and now to maintain the International Space Station (ISS). In the future, astronauts on a mission to orbit Mars or conduct operations on Mars' moon Phobos could benefit from a telerobotic presence on Mars itself, with the robot responding to commands from an astronaut in orbit or on Phobos. Having a human in the loop would improve the mission's ability to react to new discoveries and re-task the robot without inserting a lengthy communications time delay necessitated by Earth-to-Mars distances.

QUESTION 3b:

What capabilities would the Gateway need in order to provide NASA and the commercial sector with the capability to test key systems needed for exploration through telepresence?

ANSWER 3b:

The primary capability that a potential Deep Space Gateway would need to enable the crew to perform telerobotic operations on the lunar surface or in cislunar space would be a high data rate radio or optical communications system. The Gateway communications system would be used to transmit commands to telerobotic systems, to receive position and force feedback signals, and to provide high definition television for imaging the remote worksite. A virtual reality robotics workstation on the Gateway could enhance the crew's situational awareness, and enable real-time training by testing operational procedures before executing a task.

QUESTION 4:

NASA recently announced that it is engaged in an "orderly closeout" of the Asteroid Redirect Mission. No longer funding the mission is being formally proposed in the Administration's FY 2018 NASA budget request. Under what authority is NASA closing out the mission in this fiscal year, FY 2017, since NASA's FY 2018 budget has not been appropriated?

ANSWER 4:

Consistent with FY 2017 appropriations direction, formulation of the Asteroid Redirect Robotic Mission (ARRM) is discontinued; however, certain solar electric propulsion technology work is continuing.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"In-Space Propulsion: Strategic Choices and Options"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, National Aeronautics and Space Administration (NASA)

Question submitted by Rep. Steve Knight,
House Committee on Science, Space, and Technology

QUESTION 1:

It's my understanding that NASA has been working with commercial lunar lander providers through the Lunar CATALYST program, which is leading to the development of the first robotic landers capable of making a soft landing on the lunar surface since the end of the Apollo program. In one case, your Space Technology propulsion experts at NASA have been working with industry partners like Aerojet Rocketdyne and one of the lunar lander companies, Astrobotic, to develop an ISE in-space propulsion system and test it on Astrobotic's first mission in 2019.

Can you provide a little more background about how NASA is partnering with these companies to develop and test new in-space propulsion capabilities? Also, given that NASA issued an RFI for lunar lander services in last month, can you provide an update on NASA's plans to procure a mission on a commercial lunar lander over the next year or so?

ANSWER 1:

As part of NASA's effort to develop improved and lower-cost in-space chemical propulsion capabilities, the Agency has invested in a variety of technologies, such as engines that are very compact and that require much less electrical heating power to operate in space. NASA contractors in this area include Aerojet Rocketdyne, which worked with NASA in 2016 to conduct initial hotfire tests of its ISE-100 engine, and Frontier Aerospace, which is currently under contract to conduct engine development. The technology represented by these engines may eventually support various NASA missions, including lunar landers and solar system spacecraft.

While NASA continues to mature a variety of propulsion technologies, the Agency is also supporting the development of commercial lunar exploration. In 2014, NASA introduced an initiative called Lunar CATALYST (Lunar Cargo Transportation and Landing by Soft Touchdown) and entered into competitively awarded partnerships with three U.S. firms (Astrobotic Technology, Masten Space Systems, and Moon Express) to provide in-kind support to develop commercial lunar robotic landing capabilities. NASA is providing engineering expertise, hardware and software, and test facilities to these companies. The purpose of the 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. Initial flights of commercial lunar landers may begin as early as 2018, and as a result one or more of these companies will be able to market lunar payload delivery services for small instruments and technology demonstrations. Commercial lunar transportation capabilities could support science and exploration objectives such as sample returns, geophysical network deployment, resource utilization, and technology advancements.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"In-Space Propulsion: Strategic Choices and Options"

Mr. Stephen Jurczyk, Associate Administrator, Space Technology Mission Directorate, National Aeronautics and Space Administration (NASA)

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

QUESTION 1:

The National Academies' Pathways in Exploration report identified cryogenic propulsion, Nuclear Electric Propulsion, Nuclear Thermal Propulsion, and Solar Electric Propulsion as propulsion technologies "of greatest interest". Do you agree that these four technologies should be of greatest interest to NASA at this point in time? If so, what is NASA doing to pursue these research priorities?

ANSWER 1:

NASA concurs that these four propulsion technologies are of greatest interest to NASA, with one possible addition.

- Cryogenic propulsion – this is a mature chemical propulsion technology where our primary research efforts are to improve the ability to store the super-cold cryogenic propellants for long periods in space.
- Nuclear Electric Propulsion – this would employ extremely high power electric thrusters (several hundred kilowatts to mega watt) driven by electricity generated by a nuclear reactor. Space-based nuclear reactor technology is the main focus of our current research efforts along with work on higher power electric thrusters.
- Nuclear Thermal Propulsion – uses the energy in a nuclear reactor to directly heat cryogenic hydrogen propellant. Our research is completing the second year of a three-year risk reduction activity focused on developing low enriched uranium (LEU) fuel elements, reactor design, and engine design including cost and schedule estimates. These activities are critical to establishing the technical and programmatic viability of developing a nuclear thermal propulsion system based on a LEU fueled reactor. In addition, the research efforts mentioned above on long-term storage of cryogenic hydrogen propellant is an essential part of the nuclear thermal propulsion research activities.
- Solar Electric Propulsion – uses electricity generated by solar cells/panels to drive electric thrusters. Our research is focused on developing electric

thrusters at several power levels, including development of Hall thrusters to support a ~50 kW spacecraft for human and robotic exploration.

One possible addition to this list would be Hybrid Solar Electric/Chemical Propulsion which combines the benefits of high efficiency electric propulsion with the higher thrust and acceleration of chemical propulsion. All of our current research efforts on chemical and electric propulsion will contribute to advancing hybrid systems as well.

QUESTION 2:

To what extent could NASA R&D on in-space propulsion systems benefit commercial industry or other potential users of the technology? What non-NASA applications might be made possible by the technologies we discussed at the hearing?

ANSWER 2:

The most important non-NASA uses of in-space propulsion are in delivering and maintaining satellites in their proper orbits for communications, weather forecasting, Earth observation, navigation and other critical purposes. The research that we are doing for in-space propulsion is providing new non-hazardous chemical propulsion systems and far more efficient electric propulsion systems to improve the performance and reduce the cost of these space operations. In the future, commercial development of cis-lunar space and utilization of interplanetary resources could be enabled by this propulsion technology, in particular by solar electric propulsion.

QUESTION 3a:

NASA issued its In-Space Propulsion Technologies Roadmap in July 2015.

a: How has this document guided NASA in prioritizing the work needed to mature promising technologies and in establishing investment decisions? Are you still following it?

ANSWER 3a:

NASA use the Space Technology Roadmaps, in this case the In-Space Propulsion Technologies Roadmap, as an initial, broad outline of all the important in-space propulsion related technologies that could be developed to support future space exploration activities. Resource limitations prevent the Agency from investing in all the technologies outlined in the Roadmap document. The Roadmap is one of many internal and external reports and inputs NASA uses to prioritize our in-space propulsion technologies investments. Currently, NASA is making the appropriate investments in Solar Electric Propulsion, Nuclear Thermal Propulsion, Nuclear Electric Propulsion, and Cryogenic Fluid Management, which are technologies outlined in the Roadmap.

QUESTION 3b:

What are the Space Technology Directorate's next steps regarding this Roadmap? For example, do you plan to update the Roadmap? If so, when?

ANSWER 3b:

STMD incorporates the Roadmap and inputs from our key customers and stakeholders in determining which in-space propulsion technologies are near-term priority investments. Currently, STMD is also developing a Strategic Implementation Plan (SIP) which incorporates inputs from the Roadmap. STMD will publicly release a draft of its SIP in September 2017.

The Office of the Chief Technologist (OCT) is responsible for updating all the Space Technology Roadmaps on a regular basis. Currently, OCT is conducting a survey of key stakeholders to determine the future steps and content of revising the Roadmaps.

QUESTION 3c:

How are the Science Mission Directorate and the Human Exploration and Operations Mission Directorate working with you to establish the timeframes during which advanced propulsion technologies will be needed to support their projected missions?

ANSWER 3c:

STMD meets routinely with both the Science Mission Directorate (SMD) and Human Exploration and Operations Mission Directorate (HEOMD) to coordinate future mission and/or architecture technology and capability requirements along with potential timeframes. These inputs are then incorporated into STMD's strategic planning and prioritization framework and projected available resources to develop our current and future technology portfolios. Additionally, both SMD and HEOMD actively participate in the proposal evaluations and selections to ensure their mission needs are being met.

QUESTION 4a:

I understand that your directorate is examining Nuclear Thermal Propulsion (NTP) technology due to its potential to significantly reduce the time it would take to send astronauts to Mars and return them safely home. Reducing mission duration is important because it would cut the crew's exposure to galactic cosmic rays and other dangerous deep-space radiation. I am aware that NTP is also of interest to NASA because of the possible use of low enriched uranium (LEU) as nuclear fuel.

a: What is the current level of activity associated with Nuclear Thermal Propulsion?

ANSWER 4a:

Within STMD, there are currently multiple NASA-led projects that are developing key elements of an NTP system. The largest projects are devoted to developing LEU-based fuel elements for the reactor and cryogenic fluid management (CFM) technologies for long term storage of the liquid hydrogen propellant. The NTP project aims to design, manufacture, and test an LEU fuel element that meets NTP reactor performance requirements. The project is also determining the feasibility and affordability of an LEU-based NTP system to establish whether it is a viable alternative for crewed Mars missions. The most noteworthy objective of a project called eCryo in this context is a large-scale ground demonstration of liquid hydrogen storage with very low boil off of the propellant.

QUESTION 4b:

What has NASA learned to date about the possible use of LEU for an NTP?

ANSWER 4b:

NASA is collaborating with BWX Technologies and the Department of Energy to develop fuel element and reactor designs that utilize low-enriched uranium. The next progress review of that effort is in September 2017. A goal of the current NASA-led NTP project is to determine, by the end of FY18, the feasibility and affordability of an LEU-based NTP system in the thrust range of interest for a crewed Mars mission.

QUESTION 4c:

What are the technical and operational barriers to using an LEU-fueled NTP for a crewed Mars mission?

ANSWER 4c:

The main technical challenge for an LEU-fueled NTP system is designing compact fuel elements that meet the stringent requirements of thermal stability at high temperatures and mechanical stability over a wide range of operating temperature, low thermal neutron absorption and chemical compatibility. Unenriched uranium is about 99 percent U-238, which is non-fissile. Typical highly enriched uranium (HEU) fuels have enrichment levels of about 90 percent fissile U-235, whereas LEU fuel has no more than 20 percent U-235. Achieving the same performance with LEU as can be obtained with HEU requires the same number of U-235 atoms. Increasing the size of the reactor is one way to accomplish that, but the propulsion system thrust-to-weight ratio would be unacceptably high. The other approach to achieving the same overall U-235 loading is to design fuels with a much higher uranium density, which leads to materials and manufacturing challenges that must be resolved. The uranium must be alloyed with other elements to survive the reactor operating conditions, and there are very few viable choices.

QUESTION 4d:

What will be needed to enable use of NTP to support NASA's timetable of crewed missions to Mars in the2030s?

ANSWER 4d:

The current NASA-led NTP project is aimed at designing, manufacturing, and performing initial testing of an LEU fuel element that meets performance requirements. Additionally, the project will determine the overall feasibility and affordability of an LEU-based NTP system for a crewed Mars mission. To enable use of NTP for a crewed mission to Mars, the next project would need to focus on accomplishing a subscale integrated engine simulator test, along with developing preliminary designs for the full-scale reactor and engine. The subsequent major step would be completing the design and building the reactor and engine, culminating in a full-scale, full-power engine test. During the course of these efforts, a ground test approach for capturing the exhaust would need to be developed and implemented. Additionally, long-term space storage of liquid hydrogen would need to be demonstrated, utilizing cryogenic fluid management (CFM) technologies that are currently being developed. The last major step would be to design and build the space propulsion stage that would utilize the NTP system and the CFM technologies. Affordability is likely to be a huge challenge for an NTP system. Until we have more information about the feasibility and affordability of an LEU-based NTP system, it is unclear if NTP could be used for a crewed Mars mission in the 2030s.

QUESTION 5a:

Under the NERVA program, engines tested on the ground were said to have met nearly all of NASA's specifications, including thrust and engine restart. Some historians believe that the lack of national support for undertaking a human mission to Mars contributed to NERVA's termination in 1973.

a: Now that a human mission to Mars has been established as a goal, most recently in the 2017 NASA Transition Authorization Act, is it time to reexamine the applicability of nuclear propulsion for space travel?

ANSWER 5a:

While higher power, higher thrust propulsion systems could reduce trip time and thus reduce risk to crew due to exposure to the deep space environment as well as reduce the transportation logistics burden, NASA does not require advanced propulsion technologies such as NTP in the initial crewed missions to the Mars system. Nuclear propulsion is likely to be very expensive to develop. Other advanced propulsion technologies such as high-powered solar-electric propulsion (SEP) or electric propulsion (EP), combined with chemical systems, meet the needs of U.S. commercial aerospace industry while serving as the core capabilities for the initial in-space propulsion system for the Mars crewed missions.

QUESTION 5b:

If you don't think now is the right time, why not, and what is preventing nuclear propulsion from being considered in NASA's human exploration plans?

ANSWER 5b:

High cost, long development times, and a lack of utility for US commercial providers are preventing nuclear propulsion from being considered in NASA's near-term exploration plans. However, the Agency is working on the technology for potential future applications. An Advanced Exploration Systems (AES) activity was initiated in 2012 to develop and test reactor fuel elements, a critical nuclear thermal propulsion (NTP) technology development challenge. This work was transferred from AES to the Space Technology Mission Directorate (STMD) at the end of 2015. The ongoing STMD nuclear thermal propulsion research is completing the second year of a three-year risk reduction activity focused on developing low enriched uranium (LEU) fuel elements, reactor design, and engine design including cost and schedule estimates. These activities are critical to establishing the technical and programmatic viability of developing a nuclear thermal propulsion system based on a LEU fueled reactor. In addition, the research efforts mentioned above on long-term storage of cryogenic hydrogen propellant is an essential part of the nuclear thermal propulsion research activities. These activities are the essential first step in determining the applicability for future exploration. At the conclusion of this three-year activity, a determination will be made whether to continue to pursue development of the nuclear thermal propulsion technology. If continued, the next project would need to focus on accomplishing a subscale integrated engine simulator test, along with developing preliminary designs for the full-scale reactor and engine. The subsequent major step would then be completing the design and building the reactor and engine, culminating in a full-scale, full-power engine test. During the course of these efforts, a ground test approach for capturing the exhaust would need to be developed and implemented. The total cost of the full scale, full power engine test along with the development of an operational NTP system, would be significant barrier in considering NTP for future human exploration missions.

Additionally, long-term space storage of liquid hydrogen would need to be demonstrated, utilizing cryogenic fluid management (CFM) technologies that are currently being developed. The last major step would be to design and build the space propulsion stage that would utilize the NTP system and the CFM technologies.

NASA has created an exploration architecture that would allow new technologies to used when the technology and cost challenges are developed and understood.

QUESTION 6a:

Regarding Nuclear Thermal Propulsion, the National Academies stated in its Pathways to Exploration report that key facilities and personnel from the NERVA program are no longer available and that it would be difficult to produce a test facility that could contain the propulsion exhaust of a full-scale NTP system.

> a: If NASA were to pursue Nuclear Thermal Propulsion, is there a way to recapture the experience from the NERVA program so that today's engineers do not need to start from scratch?

ANSWER 6a:

All of the reports and data from the NERVA program have been examined in extensive detail by the current teams of scientists and engineers pursuing NTP development. Additionally, several of the NASA and Department of Energy team members were mentored at various points in their careers by personnel who were directly associated with the NERVA program. The advancements made and the lessons learned by the NERVA project are being directly incorporated into current NTP development projects.

QUESTION 6b:

Could the use of a computational simulation facility reduce the extent to which a test facility is needed?

ANSWER 6b:

Computer simulations are an important element of any propulsion system development effort, and NTP is no exception. However, the only way to determine the validity of models is by anchoring them to actual test data. For advanced propulsion systems that are improvements on existing implementations or entirely new approaches, the models must be modified and extended, which requires still more test data. Because there has been no NTP testing in about 45 years, some testing is needed to reacquire the knowledge on how to operate such a system safely and efficiently. In addition, no propulsion system of any type is typically flown without extensive qualification testing to ensure that it meets performance requirements in the most demanding operational environments it will experience in flight. In the propulsion realm, where testing can be quite expensive, modeling is always used to limit the number of tests to the essential minimum. Any NASA-led NTP project would certainly use modeling to the greatest extent possible due to the difficulties and cost inherent in testing a nuclear system..

QUESTION 7a:

In their prepared statements, Dr. Walker and Dr. Pancotti referred to the need for enhanced testing capabilities and facilities at NASA Centers.

a: Do you agree that additional testing facilities and capabilities are needed at NASA Centers to enable testing of thrusters with higher power levels? If you agree, what is the impact of the absence of enhanced testing capabilities on the pace of progress on developing in-space propulsion technologies? What can be done to preclude this from happening?

ANSWER 7a:

The capability needed in a test facility for an electric propulsion (EP) thruster depends heavily on the characteristics of the device. There are several different categories of EP thrusters with a wide range of characteristics, including different operating modes (such as pulsed or continuous) and different types of propellants. To perform extensive testing on the types of 100 kW class thrusters currently under development, the largest NASA test facilities would require some enhancement to increase vacuum pumping capability. However, such thrusters are currently at a relatively low technology readiness level, so the need to augment current test capabilities is not urgent.

QUESTION 7b:

If you do not agree, what is the basis for your position?

ANSWER 7b:

Please see response to question 7a.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
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July 14, 2017

Mr. Stephen Jurczyk
Associate Administrator
Space Technology Mission Directorate
National Aeronautics and
Space Administration (NASA)
300 E Street SW
Washington, DC 20546

Dear Mr. Jurczyk,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the June 29, 2017, hearing titled, *"In-Space Propulsion: Strategic Choices and Options."*

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than July 28, 2017. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than July 28, 2017.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Brian Babin

Rep. Brian Babin
Subcommittee Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"In-Space Propulsion: Strategic Choices and Options"

Mr. Stephen Jurczyk, Associate Administrator, Space Technology Mission Directorate, National Aeronautics and Space Administration (NASA)

<u>Question submitted by Ranking Member Ami Bera, House Committee on Science, Space, and Technology</u>

1. The National Academies' Pathways in Exploration report identified cryogenic propulsion, Nuclear Electric Propulsion, Nuclear Thermal Propulsion, and Solar Electric Propulsion as propulsion technologies "of greatest interest". Do you agree that these four technologies should be of greatest interest to NASA at this point in time? If so, what is NASA doing to pursue these research priorities?

2. To what extent could NASA R&D on in-space propulsion systems benefit commercial industry or other potential users of the technology? What non-NASA applications might be made possible by the technologies we discussed at the hearing?

3. NASA issued its In-Space Propulsion Technologies Roadmap in July 2015.
    a. How has this document guided NASA in prioritizing the work needed to mature promising technologies and in establishing investment decisions? Are you still following it?

    b. What are the Space Technology Directorate's next steps regarding this Roadmap? For example, do you plan to update the Roadmap? If so, when?

    c. How are the Science Mission Directorate and the Human Exploration and Operations Mission Directorate working with you to establish the timeframes during which advanced propulsion technologies will be needed to support their projected missions?

4. I understand that your directorate is examining Nuclear Thermal Propulsion (NTP) technology due to its potential to significantly reduce the time it would take to send astronauts to Mars and return them safely home. Reducing mission duration is important because it would cut the crew's exposure to galactic cosmic rays and other dangerous deep-space radiation. I am aware that NTP is also of interest to NASA because of the possible use of low enriched uranium (LEU) as nuclear fuel.
    a. What is the current level of activity associated with Nuclear Thermal Propulsion?

    b. What has NASA learned to date about the possible use of LEU for an NTP?

c. What are the technical and operational barriers to using an LEU-fueled NTP for a crewed Mars mission?

d. What will be needed to enable use of NTP to support NASA's timetable of crewed missions to Mars in the 2030s?

5. Under the NERVA program, engines tested on the ground were said to have met nearly all of NASA's specifications, including thrust and engine restart. Some historians believe that the lack of national support for undertaking a human mission to Mars contributed to NERVA's termination in 1973.
    a. Now that a human mission to Mars has been established as a goal, most recently in the 2017 NASA Transition Authorization Act, is it time to reexamine the applicability of nuclear propulsion for space travel?

    b. If you don't think now is the right time, why not, and what is preventing nuclear propulsion from being considered in NASA's human exploration plans?

6. Regarding Nuclear Thermal Propulsion, the National Academies stated in its Pathways to Exploration report that key facilities and personnel from the NERVA program are no longer available and that it would be difficult to produce a test facility that could contain the propulsion exhaust of a full-scale NTP system.
    a. If NASA were to pursue Nuclear Thermal Propulsion, is there a way to recapture the experience from the NERVA program so that today's engineers do not need to start from scratch?
    b. Could the use of a computational simulation facility reduce the extent to which a test facility is needed?

7. In their prepared statements, Dr. Walker and Dr. Pancotti referred to the need for enhanced testing capabilities and facilities at NASA Centers.
    a. Do you agree that additional testing facilities and capabilities are needed at NASA Centers to enable testing of thrusters with higher power levels? If you agree, what is the impact of the absence of enhanced testing capabilities on the pace of progress on developing in-space propulsion technologies? What can be done to preclude this from happening?

    b. If you do not agree, what is the basis for your position?

LAMAR S. SMITH, Texas
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July 14, 2017

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Associate Administrator
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300 E Street SW
Washington, DC 20546

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Rep. Brian Babin
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Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"In-Space Propulsion: Strategic Choices and Options"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, National Aeronautics and Space Administration (NASA)

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

1. The National Academies' Pathways in Exploration report identified cryogenic propulsion, Nuclear Electric Propulsion, Nuclear Thermal Propulsion, and Solar Electric Propulsion as propulsion technologies "of greatest interest". The report added that "*As the technologies for in-space propulsion are developed and matured, there will likely need to be a down-selection among the four options due to the high development costs required for each one*."
   a. Do you agree that avoiding the high development costs associated with maturing propulsion technology options could be achieved by moving to a down-selection acquisition strategy?

   b. If you do, how could such a down-selection be structured?

   c. If you do not agree, how would you proceed and what would be the cost implications?

2. What are the key decision points for making commitments on in-space propulsion technologies? What has NASA learned about how to consider trade-offs among the technology options? To what extent are trade-offs dependent on the details of a mission? To what extent will the amount of time that crews are exposed to radiation influence NASA's decision on which technologies to pursue?

3. Some space experts have advocated for using telepresence, where scientifically skilled humans work hand in hand from orbit with surface robots. These experts contend that more exploration could be conducted if it was not limited by astronauts operating on foot. In addition, by not landing on places like Mars, there would be less of a chance of introducing terrestrial contamination. The Gateway concept you introduced in March seems to provide opportunities for telepresence in exploration.
   a. What are the pros and cons of telepresence in NASA's human exploration strategy?

   b. What capabilities would the Gateway need in order to provide NASA and the commercial sector with the capability to test key systems needed for exploration through telepresence?

4. NASA recently announced that it is engaged in an "orderly closeout" of the Asteroid Redirect Mission. No longer funding the mission is being formally proposed in the Administration's FY 2018 NASA budget request. Under what authority is NASA closing out the mission in this fiscal year, FY 2017, since NASA's FY 2018 budget has not been appropriated?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"In-Space Propulsion: Strategic Choices and Options"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, National Aeronautics and Space Administration (NASA)

Question submitted by Rep. Steve Knight, House Committee on Science, Space, and Technology

1. It's my understanding that NASA has been working with commercial lunar lander providers through the Lunar CATALYST program, which is leading to the development of the first robotic landers capable of making a soft landing on the lunar surface since the end of the Apollo program. In one case, your Space Technology propulsion experts at NASA have been working with industry partners like Aerojet Rocketdyne and one of the lunar lander companies, Astrobotic, to develop an ISE in-space propulsion system and test it on Astrobotic's first mission in 2019.

   Can you provide a little more background about how NASA is partnering with these companies to develop and test new in-space propulsion capabilities? Also, given that NASA issued an RFI for lunar lander services in last month, can you provide an update on NASA's plans to procure a mission on a commercial lunar lander over the next year or so?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

October 5, 2017

Reply to Attn of: OLIA/2017-00289f:SWQ:dac

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed is material requested for the record and responses to written questions submitted by Ranking Member Bera and Representative Foster resulting from the July 18, 2017, hearing at which Dr. Jim Green and Dr. Robert Pappalardo testified regarding, "Planetary Flagship Missions: Mars Rover 2020 and Europa Clipper."

This material completes the information requested during that hearing.

Sincerely,

Rebecca Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: The Honorable Ami Bera, Ranking Member

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Planetary Flagship Missions: Mars Rover 2020 and Europa Clipper"

Dr. Jim Green, Planetary Science Division Director, Science Mission Directorate, National Aeronautics and Space Administration (NASA)

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

QUESTION 1:

With two planetary flagship missions currently in development, to what extent can the FY 2018 NASA budget request and current out-year projections support the addition of a Europa lander mission without jeopardizing the programmatic balance of the planetary science portfolio? What is the earliest date such a mission could reasonably be added without jeopardizing that balance?

ANSWER 1:

NASA's balanced Planetary Science portfolio, in accordance with guidance in the latest Planetary Science Decadal Survey, currently supports two large strategic missions in the five-year budget horizon (Mars 2020 and Europa Clipper); thus, the Europa Lander mission was not included in the FY 2018 President's budget request since it could not be accommodated without significant impacts to other programs, such as the Discovery or New Frontiers program lines. Additionally, a Europa lander was not recommended in the last planetary Decadal Survey conducted by the National Academies, which is currently undergoing its mid-term review.

Beginning design and development work on a lander before the science community is able to evaluate data from the Europa Clipper mission may impact the science return from a future lander mission.

QUESTION 2:

In light of discoveries made since the decadal survey was published and direction from Congress, NASA added Ocean Worlds to the list of mission themes for the fourth New Frontiers Announcement of Opportunity and is studying a lander mission to Europa. Under current fiscal constraints, does the NASA planetary science program have the flexibility it needs to respond to new discoveries in a way that maximizes the science return while also staying true to the science goals and priorities recommended by the decadal survey? How does and should NASA engage the science community in the process of responding to new discoveries?

ANSWER 2:

As in the past, NASA will continue to rely on the science community to identify and prioritize leading-edge scientific questions and the observations required to answer them – primarily through the National Academies decadal survey process. Despite fiscal constraints, NASA is dedicated to being responsive to the top priorities within the current decadal survey, as evident through our Mars 2020 and Europa Clipper missions.

NASA is also committed to planning for a robust planetary science future. For example, NASA recently convened an ad hoc committee via the National Academies to review the response of NASA's Planetary Science program to the 2011 Decadal Survey. In addition to assessing the degree to which NASA's current planetary science program addresses the strategies and priorities outlined in the decadal, the committee will recommend any actions that could be taken to optimize the science value of the planetary science program, including how to take into account emergent discoveries since the decadal in the context of current and forecasted resources.

QUESTION 3:

A *Science* Magazine article published in May revealed that, despite the fact that at least 25 percent of planetary scientists are women; women have made up just 15 percent of planetary mission science teams over the past 15 years. Can you give us some insight into what steps NASA is taking to increase the representation of women on its planetary science missions?

ANSWER 3:

NASA is committed to diverse representation within our missions and our Planetary Science Division (PSD) specifically has been working over the past few years on a multidimensional strategy to increase the representation of women. While PSD has various missions and teams that have women as Principal Investigators or deputies (four of the five Principal Investigators selected for Phase A studies in the last Discovery competition were women), we are also striving to ensure that participation by women scientists and engineers is growing in in leadership areas such as:

- Discipline scientists, program executives and program officers
- Planetary Science Advisory Council (PAC) membership
- Review panels

This strategy is based on the idea that when particular attention is paid to ensuring the infrastructure is diverse, it will not only provide opportunities for women in planetary science but also encourage young women scientists in finding role models to help position themselves on leadership paths. The strategy has already shown to be successful; for example, our current (and previous) PAC chairperson is a woman scientist. Along with our review panels, the PAC membership was and continues to have a solid female representation.

QUESTION 4:

NASA has managed several large flagship missions in planetary science as well as in other NASA science divisions. How is that experience being leveraged for the Mars 2020 and Europa Clipper missions? Has NASA made any changes to the way it manages these two missions based on the experience gained and lessons learned from past flagship missions? If so, what are they?

ANSWER 4:

Lessons learned are an integral part of NASA missions and as an agency, we strive to implement new and innovative ways for our workforce to share their knowledge not only as part of flagship missions, but also as part of their normal everyday work. In particular, NASA's three major project management requirements documents specify the sharing of knowledge from lessons learned and direct project managers to develop a plan for collecting and sharing lessons learned.

For example, NASA completed a formal Mars Science Laboratory (MSL) Lessons Learned Study, which the Mars 2020 team is utilizing for guidance. Mars 2020 is also strategically using heritage technology based on the MSL Curiosity rover to help manage cost and risk for a new flagship mission.

Based upon our experience with previous flagship missions, NASA transitioned to a confidence-level budgeting approach for all of our external cost commitments. Each mission is required to be budgeted at a 70 percent cost confidence, which ensures that the aggregate portfolio of missions is highly likely to remain within the forecast costs. We have developed tools to develop confidence-level budgets, and performance data shows that the aggregate SMD portfolio remains under cost commitments for missions over the last 6 years. Mars 2020 and Europa Clipper are both following this process.

For the Europa Clipper Mission, two additional steps are being taken to ensure cost control: (1) Margin on obligations-to-go are being reported to HQ each month for each instrument, as instruments have historically had significant cost growth; and, (2) A new tool has been developed to map each instrument's capabilities onto the science requirements, allowing analysis of possible overlap between instruments and identification of the consequence on science objectives if an instrument must be reduced in capability. Both of these two approaches are new, and Europa Clipper will be the first mission to use them.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Planetary Flagship Missions: Mars Rover 2020 and Europa Clipper"

Dr. Robert Pappalardo, Europa Clipper Project Scientist, Jet Propulsion Laboratory, California Institute of Technology

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

QUESTION 1:

The 2017 Consolidated Appropriations Act directs NASA to launch the Europa Clipper aboard an SLS launch vehicle. However, NASA has reported to the Committee that SLS will not have its first test flight until no earlier than Fall 2019. When does the Europa Clipper project need to select a launch vehicle? What is the impact of launch vehicle uncertainty on the Europa Clipper project's ability to proceed through development within its preliminary cost and schedule estimates?

ANSWER 1:

NASA plans to baseline the Europa Clipper mission in FY 2018 and the selection of the launch vehicle is targeted for no later than the project Critical Design Review in late 2019, but potentially sooner. Preliminary cost and schedule estimates incorporate launch vehicle uncertainty so there is minimal to no impact on the project's ability to proceed through development within the identified ranges.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Planetary Flagship Missions: Mars Rover 2020 and Europa Clipper"

Dr. Jim Green, Planetary Science Division Director, Science Mission Directorate, National Aeronautics and Space Administration (NASA)

Question submitted by Rep. Bill Foster,
House Committee on Science, Space, and Technology

QUESTION 1:

The Apollo lunar landing program cost $24B in 1960s dollars over 10 years. That means NASA set aside 4 percent of U.S. GDP to do Apollo. Today, 50 years later, NASA's budget is about $19B per year which is less than one half of one percent of GDP.

If we are serious about this Mission to Mars, we need to get serious about producing a realistic cost estimate. Do you have what you believe is a realistic upper and lower limit to the cost for getting to Mars? If so, please share that estimate with this subcommittee.

ANSWER 1:

The NASA Transition Authorization Act calls on NASA "to enable humans to explore Mars and other destinations by defining a series of sustainable steps and conducting mission planning, research and technology development on a timetable that is technically and fiscally possible". In keeping with this direction, NASA has formulated a set of principles for sustainable exploration that begin with fiscal realism and include a gradual buildup of capabilities over time and the infusion of new technologies as they mature.

NASA's strategy is designed to embrace infusion of new technologies and new commercial and international partnerships from the present day through the accomplishment of human presence on Mars. Because the timing and impact of these are not quantifiable in advance, establishing a cost estimate for the whole endeavor is impractical.

NASA's overall exploration goals and objectives, strategy, hardware and missions, and key decision timeframes will be articulated by the Human Exploration Roadmap due to the Congress on December 1 of this year. As NASA learns from initial missions using SLS and Orion, and the development of deep space habitation and in-space propulsion, the Agency will formulate cost and schedule details of future goals and hardware, and this analysis will be reflected in future budget requests so the Congress will annually be updated on projected accomplishments and resource requirements for the next five years.

Material requested for the record on page 70, line 1560, by Representative Webster during the July 18, 2017, hearing at which Dr. Jim Green and Dr. Robert Pappalardo testified.

The Radioisotope Thermal Generators (RTGs) on Voyager 1 and 2 currently produce about 250 watts each.

Material requested for the record on page 70, line 1563, by Representative Webster during the July 18, 2017, hearing at which Dr. Jim Green and Dr. Robert Pappalardo testified.

The spacecraft requires just above 200 watts of power to run the necessary systems to maintain its orientation and to communicate with Earth. The Voyagers lose approximately four watts per year through radioactive decay of the Plutonium 238 and reduced efficiency of the thermal interface. In roughly 13 years, insufficient wattage will require NASA to shut down the final instruments. At that point, the Voyagers will not be able to provide any scientific information of their environment.

Material requested for the record on page 71, line 1580, by Representative Webster during the July 18, 2017, hearing at which Dr. Jim Green and Dr. Robert Pappalardo testified.

The Voyagers will not in their foreseeable future be too far away for us to pick up their signal.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-6301
(202) 225-6371
www.science.house.gov

August 2, 2017

Dr. Jim Green
Planetary Science Division Director
Science Mission Directorate
National Aeronautics and
Space Administration (NASA)
300 E Street SW
Washington, D.C. 20546-0001

Dear Dr. Green,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the July 18, 2017, hearing titled, *"Planetary Flagship Missions: Mars Rover 2020 and Europa Clipper."*

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than August 16, 2017. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than August 16, 2017.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Brian Babin

Rep. Brian Babin
Subcommittee Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Planetary Flagship Missions: Mars Rover 2020 and Europa Clipper"

Dr. Jim Green, Planetary Science Division Director, Science Mission Directorate, National Aeronautics and Space Administration (NASA)

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

1. With two planetary flagship missions currently in development, to what extent can the FY 2018 NASA budget request and current out-year projections support the addition of a Europa lander mission without jeopardizing the programmatic balance of the planetary science portfolio? What is the earliest date such a mission could reasonably be added without jeopardizing that balance?

2. In light of discoveries made since the decadal survey was published and direction from Congress, NASA added Ocean Worlds to the list of mission themes for the fourth New Frontiers Announcement of Opportunity and is studying a lander mission to Europa. Under current fiscal constraints, does the NASA planetary science program have the flexibility it needs to respond to new discoveries in a way that maximizes the science return while also staying true to the science goals and priorities recommended by the decadal survey? How does and should NASA engage the science community the process of responding to new discoveries?

3. A *Science* Magazine article published in May revealed that, despite the fact that at least 25 percent of planetary scientists are women; women have made up just 15 percent of planetary mission science teams over the past 15 years. Can you give us some insight into what steps NASA is taking to increase the representation of women on its planetary science missions?

4. NASA has managed several large flagship missions in planetary science as well as in other NASA science divisions. How is that experience being leveraged for the Mars 2020 and Europa Clipper missions? Has NASA made any changes to the way it manages these two missions based on the experience gained and lessons learned from past flagship missions? If so, what are they?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Planetary Flagship Missions: Mars Rover 2020 and Europa Clipper"

Dr. Jim Green, Planetary Science Division Director, Science Mission Directorate, National Aeronautics and Space Administration (NASA)

Question submitted by Rep. Bill Foster, House Committee on Science, Space, and Technology

1. The Apollo lunar landing program cost $24 billion in 1960s dollars over 10 years. That means NASA set aside 4 percent of U.S. GDP to do Apollo. Today, 50 years later, NASA's budget is about $19 billion per year which is less than one half of one percent of GDP.

   If we are serious about this Mission to Mars, we need to get serious about producing a realistic cost estimate. Do you have what you believe is a realistic upper and lower limit to the cost for getting to Mars? If so, please share that estimate with this subcommittee.

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

September 13, 2017

Reply to Attn of: OLIA/2017-00293f:SWQ

The Honorable Ted Cruz
Chairman
Subcommittee on Science, Space and Competitiveness
Committee on Commerce, Science,
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Senator Sullivan resulting from the July 13, 2017, hearing at which Mr. Robert Cabana testified regarding "Reopening the American Frontier: Promoting Partnerships Between Commercial Space and the U.S. Government to Advance Exploration and Settlement."

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

cc: Ranking Member Edward Markey

Enclosure

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION:
QUESTIONS FOR THE RECORD

HEARING ON
REOPENING THE AMERICAN FRONTIER: PROMOTING PARTNERSHIPS BETWEEN COMMERCIAL SPACE AND THE U.S. GOVERNMENT TO ADVANCE EXPLORATION AND SETTLEMENT
JULY 13, 2017

Written Questions Submitted to Mr. Robert Cabana, Director, NASA Kennedy Space Center

Submitted by Senator Dan Sullivan

Challenges Hindering DOD-Commercial Partnerships

Question 1: Earlier this year, in response to a provision that I included in the FY2017 National Defense Authorization Act (NDAA), the Department of Defense (DOD) released an Arctic strategy that among other points, highlights severe challenges caused by the limited satellite and terrestrial communications above 65 degrees north. When the DOD needs to quickly address gaps in capabilities, commercial partnerships can—where appropriate—play a key role in filling these needs.

What are the primary challenges that have hindered or prevented you from working with the U.S. government to fill critical gaps in U.S. space capabilities, like the domain awareness and communications gaps in the Arctic?

Answer 1: NASA employs several kinds of commercial partnership mechanisms to address U.S. space capabilities, including – but not limited to – Federal Acquisition Regulation (FAR)-based contracts to fulfill Agency requirements, as well as funded and unfunded Space Act Agreements (SAAs), which support and encourage commercial innovation. The Commercial Resupply Service (CRS) contracts, under which Space Exploration Technologies (SpaceX) and Orbital ATK have been providing cargo resupply to the International Space Station (ISS), are examples of the former. NASA's Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) initiative, which has established multiple no-funds-exchanged SAA partnerships with U.S. private sector entities, is an example of the latter. The purpose of these SAAs is to encourage the development of robotic lunar landers that can be integrated with U.S. commercial launch capabilities to deliver payloads to the lunar surface. NASA looks forward to continuing commercial partnerships to address Agency requirements and to support commercial innovation in the future.

As to addressing U.S. space capabilities such as domain awareness and military communications in the Arctic, the Committee may wish to contact the Department of Defense for details on their efforts in these areas.

Internet Access in Rural Areas

Question 2: In Alaska, many places do not have any connectivity and many times are not even connected by road. It is costly to deploy telecommunications infrastructure, and while these communities are extremely innovative, a lack of connectivity hinders business growth and increased economic activity.

Commercial space provides the possibility of increased communications, including satellite-based broadband internet, at a reduced cost. Especially if the cost of launches continues to decline, this could provide real benefits to consumers in extremely rural places like Alaska.

How can recent advances in commercial space help provide broadband-level internet to the most rural areas?

Answer 2: While NASA defers to private industry to articulate the business case supporting the provision of services to specific customers, a number of companies currently offer launch services and satellite-based communications services that could potentially increase broadband Internet access in rural areas.

Question 3: Is latency still an issue?

Answer 3: Please see response to Question #2, above. NASA defers to private industry on the specifics for their ability to provide broadband Internet service to rural areas.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
REOPENING THE AMERICAN FRONTIER: PROMOTING PARTNERSHIPS BETWEEN COMMERCIAL SPACE AND THE U.S. GOVERNMENT TO ADVANCE EXPLORATION AND SETTLEMENT
JULY 13, 2017

Written Questions Submitted to Mr. Robert Cabana, Director, NASA Kennedy Space Center

Submitted by Senator Dan Sullivan

<u>Challenges Hindering DOD-Commercial Partnerships</u>

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What are the primary challenges that have hindered or prevented you from working with the U.S. government to fill critical gaps in U.S. space capabilities, like the domain awareness and communications gaps in the Arctic?

<u>Internet Access in Rural Areas</u>

Question 2. In Alaska, many places do not have any connectivity and many times are not even connected by road. It is costly to deploy telecommunications infrastructure, and while these communities are extremely innovative, a lack of connectivity hinders business growth and increased economic activity.

Commercial space provides the possibility of increased communications, including satellite-based broadband internet, at a reduced cost. Especially if the cost of launches continues to decline, this could provide real benefits to consumers in extremely rural places like Alaska.

How can recent advances in commercial space help provide broadband-level internet to the most rural areas?

Question 3. Is latency still an issue?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

November 3, 2017

Reply to Attn of: OLIA/2017-00363f:SWQ

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Ranking Members Bera and Johnson resulting from the September 7, 2017, hearing at which Mr. Jason Crusan testified regarding ***"Private Sector Lunar Exploration."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: The Honorable Ami Bera, Ranking Member

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Private Sector Lunar Exploration"

Mr. Jason Crusan, Director, Advanced Exploration Systems, NASA

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

Question 1:

A number of companies that aspire to reach the Moon have discussed sending their vehicles and personnel to areas of the lunar surface where artifacts remain from prior U.S. government landings and activities on the Moon, including from the Apollo program. Some of these companies have also expressed interest in bringing back artifacts from prior lunar landings. Do you believe that prior landing sites and artifacts, such as those from the Apollo missions, should be accessible to commercial interests or should the sites be protected for historical and scientific reasons?

Answer 1:

In 2011, NASA established guidelines to protect lunar historic sites and preserve ongoing and future science on the Moon. NASA recognized that many spacefaring nations and commercial entities were making plans to send spacecraft to the Moon, with some even planning to land near and/or visit historic sites with rovers or hopping spacecraft. The Agency, in consultation with industry, historians, scientists and other stakeholders, assembled the guidelines using, for example, data from previous lunar studies and analysis of the unmanned lander Surveyor 3's samples after Apollo 12 landed nearby in 1969. Experts from the historic, scientific, flight-planning communities as well as representatives from the Google Lunar X-Prize contestants also contributed to the technical recommendations. The guidelines do allow for rovers and hoppers to safely access many sites and provide suggested areas of scientific or technical interest. The guidelines do not represent mandatory U.S. or international requirements, rather NASA provided them to help the lunar mission planners preserve and protect historic lunar artifacts and potential science opportunities for future missions.

Please see the following link to access the guidelines noted above:

https://www.nasa.gov/pdf/617743main_NASA-USG_LUNAR_HISTORIC_SITES_RevA-508.pdf

Question 1a:

If you believe that the Apollo sites should be accessible to commercial interests what do you envision as being an acceptable level of access?

Answer 1a:

Yes, NASA believes that Apollo and other lunar heritage and scientific sites should be accessible to commercial interests; hence Agency efforts to establish the voluntary guidelines outlined in the response to Question #1, above. In addition, NASA can provide additional guidance to mission planners as needed.

Question 1b:

If you believe that the Apollo sites should be protected for historical and scientific reasons, how do you think we should best protect those artifacts from being disturbed by future missions to the Moon?

Answer 1b:

Please see response to Question #1, above. The guidelines established by NASA do not represent mandatory U.S. or international requirements, they are intended to help lunar mission planners preserve and protect historic lunar artifacts and potential science opportunities for future missions (NASA, as the current primary customer for many of the companies planning lunar exploration missions, does not plan to fund landed missions that would impinge upon or otherwise negatively impact these sites).

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Private Sector Lunar Exploration"

Mr. Jason Crusan, Director, Advanced Exploration Systems, NASA

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

Question 1:

In their written statements, Mr. Thornton, Mr. Richards, and Dr. Sowers discuss private sector plans to extract water from the Moon's water ice. The results from previous lunar probes indicate that a significant amount of water ice is likely to be present at the lunar poles. The scientific community has placed a priority on investigating the South Pole Aitken Basin of the Moon to investigate the early stages of the Earth-Moon system and to help understand how and when volatiles were delivered to Earth.

Question 1a:

What impact would potential private sector resource extractions at the lunar poles have on the science community's research activities at those locations?

Answer 1a:

Located on the Moon's far side southern polar region, the South Pole-Aitken (SPA) basin is the largest and oldest recognized basin on the Moon and is likely to contain some fraction of the mineralogy of the Moon's lower crust. Because of this, scientists are interested in closer study of the basin and mission concepts to return a sample of material from the SPA basin terrain have been proposed in order to provide critical information to understand the history of Earth's Moon. At this time, no such mission has been initiated, however, it is included in the list of potential missions under the current New Frontiers 4 solicitation. It is possible that future lunar commercial transportation capabilities could support analogous science objectives, and NASA will continue to seek opportunities to work with the private sector to enhance and complement our own lunar science and research plans.

Question 1b:

How would NASA balance its involvement with the private sector activities and those of the scientific community?

Answer 1b:

NASA is continuing the scientific investigation of the Moon through a variety of spacecraft, including the Lunar Reconnaissance Orbiter, as well as several CubeSats to be launched as secondary payloads on Exploration Mission-1 (Lunar Polar Hydrogen Mapper, Lunar Flashlight, Lunar IceCube, and Lockheed Martin's LunIR mission). At the same time, the Agency is supporting the development of private sector lunar capabilities that can be utilized for both commercial and scientific benefit.

The National Aeronautics and Space Act of 1958 (as amended) assigns NASA the mission to "seek and encourage, to the maximum extent possible, the fullest commercial use of space". NASA recognizes that private sector activities in space have the potential to improve access to the Moon and other destinations by both NASA and non-NASA customers. Through initiatives such as Lunar Cargo Transportation and Landing by Soft Touchdown (CATALYST), NASA continues to encourage private ventures to develop both the space capabilities and the associated business plans that could expand the opportunities to send NASA science, exploration, or technology demonstration payloads to the Moon or other destinations in space. To the extent that private investments can help lower the cost of space access and increase the frequency of missions, NASA will seek ways to work with the private sector to enhance and complement our own plans for space science and exploration.

In 2014, NASA introduced Lunar CATALYST. The purpose of the 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 and could also enable new science and exploration missions of interest to the larger scientific and academic communities. These emerging commercial capabilities, in turn, have the potential to make space exploration more affordable and sustainable as NASA expands human presence into deep space.

Future commercial lunar transportation capabilities could support science and exploration objectives such as sample returns, geophysical network deployment, resource utilization, and technology advancements.

In the longer term, commercial development of lunar resources (a stated goal of many nascent commercial lunar companies) requires scientific understanding of the Moon. For example, data about lunar geology, volatiles, and regolith trafficability etc., is knowledge required to benefit commercial interests and is also of interest to the broader scientific communities. Therefore, NASA believes both sectors could benefit.

Question 1c:

What can be done now to ensure that the Moon is explored for the mutual benefit of the science community and the private sector?

Answer 1c:

Please see response to Question #1b, above. NASA's support for the development of commercial lunar capabilities is intended to also benefit the Agency's own science and exploration missions.

Question 2:

Does NASA require that partnerships with industry on lunar exploration contribute in some way to advancing NASA's mission? If not, why not? To what extent are the current partnerships between NASA and the private sector primarily serving NASA's objectives and to what extent are they primarily serving private sector interests?

Answer 2:

An important part of NASA's strategy is to partner with the commercial space industry to assist the Agency in achieving its strategic goals and objectives. NASA's collaborative efforts are fostering innovation and a growing commercial space industry, while transforming capabilities and accelerating technologies needed to achieve national strategic goals.

As noted above, NASA's Lunar CATALYST was designed 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. NASA's collaboration with industry through CATALYST, such as providing technical expertise and access to NASA's testing facilities, is a modest investment that has increased the private sector's rate of progress. Future commercial lunar transportation capabilities could make new science and exploration missions more affordable and viable, such as sample returns, geophysical network deployment, resource utilization, and technology advancements.

Earlier this year, NASA issued a Request for Information (RFI) seeking ideas from industry for the Agency to possibly participate in existing or future commercial missions to the Moon. The Agency is interested in assessing the availability of a commercial launch from Earth to the lunar surface to provide landing services as early as Fiscal Year 2018, and through the next decade. This approach offers the Agency the potential to simultaneously address high-priority science, critical strategic objectives related to exploration, and technology demonstration, using commercially-provided domestic space services and hardware.

Question 3:

NASA has experience partnering with the private sector in space activities. Two companies are flying resupply missions to the ISS. NASA is also collaborating with U.S. companies to develop systems for transporting astronauts to the ISS to end our reliance on Russian rockets. How do the goals of the Lunar CATALYST program compare with the goals of the other public-private partnerships NASA has been carrying out, and are there any "lessons learned" that should be applied to the lunar partnerships?

Answer 3:

The Agency employs several kinds of mechanisms to work with the commercial sector to advance U.S. space capabilities, including – but not limited to – Federal Acquisition Regulation (FAR)-based contracts to fulfill Agency requirements, and partnerships using Space Act Agreements (SAAs), just two one of the mechanisms NASA uses to support and encourage

commercial innovation. The Commercial Resupply Service (CRS) contracts, under which Space Exploration Technologies (SpaceX) and Orbital ATK have been providing cargo resupply to the International Space Station (ISS), are examples of the former. NASA's Commercial Orbital Transportation Services (COTS) and NASA's Lunar CATALYST initiatives both represent examples of NASA using Space Act Agreements to provide support to industry partners developing commercial space capabilities that could eventually support both government and commercial users. Both initiatives required industry to focus on the commercial market by keeping "skin in the game." While COTS provided for payments to industry, Lunar CATALYST is a no-funds-exchanged activity and provides only in-kind contributions in the form of NASA expertise and access to NASA facilities. NASA is pleased with the progress being made by our three Lunar CATALYST commercial partners. The particular approaches to be employed in future lunar partnerships – as well as applicable lessons learned from previous partnerships – will be dependent on a variety of factors.
Question 4a:

The House Appropriations Committee singled out the Lunar CATALYST program in the legislative report accompanying its FY 2018 Appropriations bill. The Committee proposed up to $30M be provided for Lunar CATALYST activities, including a lunar lander demonstration.

a. What is the current funding level for the Lunar CATALYST program?

Answer 4a:

NASA's Lunar CATALYST initiative is currently supporting three companies through no-exchange-of-funds Space Act Agreements. NASA is providing engineering expertise, hardware and software, and test facilities to these companies. NASA Advanced Exploration Systems (AES) lander technology activities planned in FY 2018 include $20 million for both Lunar CATALYST Partner and general Lander Support along with beginning the funding required to support commercial landed services.

Question 4b:

Based on the plans of some companies and the Google Lunar XPRIZE competition under which participant teams are required to land on the Moon, would lunar lander demonstrations happen anyway regardless of additional NASA investment? Is there any benefit to conducting an additional demonstration in which NASA is involved? If so, what?

Answer 4b:

NASA defers to private sector organizations for details about their business plans and levels of investment in lunar missions. As noted above, the Agency is supporting the development of commercial lunar capabilities through efforts such as Lunar CATALYST. NASA believes such capabilities can benefit both commercial and Government-sector space exploration.

Question 4c:

If the provision for a NASA lunar lander demonstration was included, how would NASA ensure that the demonstration provider is competitively selected?

Answer 4c:

NASA's Lunar CATALYST partners were competitively selected. The Agency is considering issuing a solicitation for commercial landed services along with solicitation(s) for small payloads (<10 kg) that could be available for commercial transportation to the Moon as early as FY 2018. Should NASA issue such a lunar cargo transportation solicitation, the provider(s) would be selected on a competitive basis.

Question 5:

Under Lunar CATALYST agreements between NASA and the partners, what milestones do partners need to meet and what is the nature of those milestones? To date, have Lunar CATALYST partners met their agreed upon milestones, including financial milestones? If not, which milestones are proving to be the most challenging? What will NASA do if milestones are not met?

Answer 5:

The Lunar CATALYST partners must achieve technical as well as financial milestones under their no-funds-exchanged Space Act Agreements. The technical milestones include major events, such as completing design reviews, assembly and environmental testing of lander subsystems, and rocket engine tests. The financial milestones ensure that the companies are developing viable business plans and raising sufficient funds from private investors and payload customers.

- Astrobotic has completed 7 of 20 milestones, including the Preliminary Design Review for their Peregrine lander. Astrobotic has also booked nine payload customers for their first flight.

- Masten Space Systems has completed 14 of 22 milestones, including testing of the main engine for their terrestrial demonstrator vehicle and all of their financial milestones.

- Moon Express has completed 7 of 16 milestones, including detailed design of their MX-1E lander, tethered flight testing, full funding for their first lunar mission, and signing a launch contract with Rocket Lab.

The Lunar CATALYST partners plan to launch their first lunar missions in the 2018 to 2020 timeframe. To give the partners more time to build and test flight-ready landers, NASA has extended the existing Space Act Agreements for two additional years through FY 2019.

The milestones do not drive any payment decisions, since these are no-exchange-of-funds agreements. However, NASA uses the milestones to provide insight into the activities of the partners, to foster clear communication, and to confirm that strong and regular progress continues to be made by the partners.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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September 25, 2017

Mr. Jason Crusan
Director
Advanced Exploration Systems
National Aeronautics
and Space Administration
300 E Street SW
Washington, D.C. 20546-0001

Dear Mr. Crusan,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the September 7, 2017, hearing titled, *"Private Sector Lunar Exploration."*

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than October 9, 2017. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than October 9, 2017.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Brian Babin

Rep. Brian Babin
Subcommittee Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Private Sector Lunar Exploration"

Mr. Jason Crusan, Director, Advanced Exploration Systems, NASA

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

1. In their written statements, Mr. Thornton, Mr. Richards, and Dr. Sowers discuss private sector plans to extract water from the Moon's water ice. The results from previous lunar probes indicate that a significant amount of water ice is likely to bepresent at the lunar poles. The scientific community has placed a priority on investigating the South Pole Aitken Basin of the Moon to investigate the early stages of the Earth-Moon system and to help understand how and when volatiles were delivered to Earth?
    a. What impact would potential private sector resource extractions at the lunar poles have on the science community's research activities at those locations?
    b. How would NASA balance its involvement with the private sector activities and those of the scientific community?
    c. What can be done now to ensure that the Moon is explored for the mutual benefit of the science community and the private sector?
2. Does NASA require that partnerships with industry on lunar exploration contribute in some way to advancing NASA's mission? If not, why not? To what extent are the current partnerships between NASA and the private sector primarily serving NASA's objectives and to what extent are they primarily serving private sector interests?
3. NASA has experience partnering with the private sector in space activities. Two companies are flying resupply missions to the ISS. NASA is also collaborating with U.S. companies to develop systems for transporting astronauts to the ISS to end our reliance on Russian rockets. How do the goals of the Lunar CATALYST program compare with the goals of the other public-private partnerships NASA has been carrying out, and are there any "lessons learned" that should be applied to the lunar partnerships?

4. The House Appropriations Committee singled out the Lunar CATALYST program in the legislative report accompanying its FY 2018 Appropriations bill. The Committee proposed up to $30 million be provided for Lunar CATALYST activities, including a lunar lander demonstration.

    a. What is the current funding level for the Lunar CATALYST program?

    b. Based on the plans of some companies and the Google Lunar XPRIZE competition under which participant teams are required to land on the Moon, would lunar lander demonstrations happen anyway regardless of additional NASA investment? Is there any benefit to conducting an additional demonstration in which NASA is involved? If so, what?

    c. If the provision for a NASA lunar lander demonstration was included, how would NASA ensure that the demonstration provider is competitively selected?

5. Under Lunar CATALYST agreements between NASA and the partners, what milestones do partners need to meet and what is the nature of those milestones? To date, have Lunar CATALYST partners met their agreed upon milestones, including financial milestones? If not, which milestones are proving to be the most challenging? What will NASA do if milestones are not met?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Private Sector Lunar Exploration"

Mr. Jason Crusan, Director, Advanced Exploration Systems, NASA

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

1. A number of companies that aspire to reach the Moon have discussed sending their vehicles and personnel to areas of the lunar surface where artifacts remain from prior U.S. government landings and activities on the Moon, including from the Apollo program. Some of these companies have also expressed interest in bringing back artifacts from prior lunar landings. Do you believe that prior landing sites and artifacts, such as those from the Apollo missions, should be accessible to commercial interests or should the sites be protected for historical and scientific reasons?
    a. If you believe that the Apollo sites should be accessible to commercial interests what do you envision as being an acceptable level of access?
    b. If you believe that the Apollo sites should be protected for historical and scientific reasons, how do you think we should best protect those artifacts from being disturbed by future missions to the Moon?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

November 7, 2017

Reply to Attn of: OLIA/2017-00395:SWQ:dac

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Representative Perlmutter to Dr. Thomas Zurbuchen resulting from the September 28, 2017, hearing, ***"The Great American Eclipse: To Totality and Beyond."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: Ranking Member Ami Bera
Ranking Member Dan Lipinski

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"The Great American Eclipse: To Totality and Beyond"

Dr. Thomas Zurbuchen, Associate Administrator, Science Mission Directorate, National Aeronautics and Space Administration

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

QUESTION 1:

How specifically will this eclipse contribute to our understanding of the Sun and more specifically space weather?

ANSWER 1:

To understand the origins of space weather, its impact upon our technological society and ultimately predict it much like we do for terrestrial weather, requires detailed understanding of the Sun's outer atmosphere, the corona. This dynamic region -- especially the lowest part of the corona -- is the origination point for the giant eruptions such as solar flares, coronal mass ejections and bursts of solar energetic particles which can cause space weather events at Earth. We can observe this special region in many different wavelengths of light from missions in space -- but visible light, the light we see with our own eyes, is not one of these wavelengths. We can see this lower part of the corona only when its dim light is revealed during a total solar eclipse.

Consequently, a total solar eclipse is a golden opportunity for solar science, dependent wholly on using telescopes on the ground and in aircraft to capitalize on the singular eclipse geometry visible only from Earth's perspective. The August 2017 total solar eclipse was especially important for NASA and its science partners because the eclipse covered thousands of miles of accessible land. This allowed for observations of the relatively short period of totality (roughly 2 minutes) at different locations and with different instruments amounting to more than an hour of consecutive coronal observations. NASA funded 11 ground-based and aircraft studies, including six designed to make critical measurements of the corona. These different studies are helping to piece together puzzles of our dynamic Sun. All the experiments provide important information. Two notable ones include telescope measurements of the temperature and motions of material in the corona and high-speed images of the corona taking by high altitude research aircraft. This information will help to provide an understanding of the triggers of energy release driving space weather eruptions and the overall flow of energy through the corona respectively.

QUESTION 2:

How will current and future facilities, including the Daniel K. Inouye Solar Telescope and the National Solar Observatory's Integrated Synoptic Program, work together with other facilities and agencies to enhance our knowledge of and future prediction of space weather?

ANSWER 2:

NSF's Daniel K. Inouye Solar Telescope (DKIST) will be the world's most powerful ground-based solar observatory poised to answer fundamental questions regarding the Sun and especially its magnetic field. DKIST will make unprecedented high-resolution images of the Sun and its magnetic fields, down to a scale of 20-30 km on the Sun. It will have a suite of instruments capable of observing the Sun and its corona in specific lines ranging from the near-ultraviolet, to the visible, all the way into the infrared. DKIST will be used by scientists to explore the fundamental physics behind the solar magnetic fields that drive phenomena like solar flares, coronal mass ejections, and the solar wind, all of which constitute the space weather that impacts the Earth.

While DKIST will provide the detailed views of the Sun necessary to understand the fundamental physics that drive space weather, accurate predictions of space weather require long-term, full-disk monitoring of the Sun on a continuous basis. The National Solar Observatory's Integrated Synoptic Program (NISP) is well suited to provide the high-cadence, large field-of-view capabilities required for space weather prediction. NISP consists of the Global Oscillations Network Group (GONG) and the Synoptic Optical Long-term Investigations of the Sun (SOLIS) facilities. GONG observes the entire disk of the Sun 24/7, 365 days per year from six stations spread around the globe. It is this continuous, full-disk data that is vital to the space weather prediction models of NOAA, NASA, and the DoD.

Both DKIST and NISP will be able to exploit synergies with the current suite of NASA Heliophysics spacecraft observing the Sun remotely as well as upcoming space missions like the NASA's Parker Solar Probe and the joint European Space Agency/NASA Solar Orbiter; expected to launch in 2018 and 2019, respectively. These missions will make in-situ measurements of the inner heliosphere and the solar corona that will complement the high-resolution imaging capability of NSF's DKIST and the full-disk, synoptic capabilities of NISP. NSF and NSO have been reaching out to the space-based solar community through a series of topic-based workshops designed to introduce the community to the science capabilities of DKIST. At the same time, the Parker Solar Probe and Solar Orbiter science teams have stood up a working group to plan for collaborative science. One upcoming workshop, to be held at the Johns Hopkins University's Applied Physics Lab, is specifically targeted at exploring the ways in which DKIST, Parker Solar Probe, and Solar Orbiter can be combined to enhance our understanding of the Sun and the space weather it drives.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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October 13, 2017

Dr. Thomas Zurbuchen
Associate Administrator
Science Mission Directorate
National Aeronautics and Space Administration
300 E Street NW
Washington, D.C. 20546-0001

Dear Dr. Zurbuchen,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the September 28, 2017 hearing titled, *"The Great American Eclipse: To Totality and Beyond."*

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than **October 27, 2017**. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than October 27, 2017.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Barbara Comstock
Chairwoman
Subcommittee on Research
and Technology

Brian Babin
Chairman
Subcommittee on Space

cc: Rep. Dan Lipinski
Ranking Member
Subcommittee on Research and Technology

Rep. Ami Bera
Ranking Member
Subcommittee on Space

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"The Great American Eclipse: To Totality and Beyond"

Dr. Thomas Zurbuchen, Associate Administrator, Science Mission Directorate, National Aeronautics and Space Administration

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

1. How specifically will this eclipse contribute to our understanding of the Sun and more specifically space weather?

2. How will current and future facilities, including the Daniel K. Inouye Solar Telescope and the National Solar Observatory's Integrated Synoptic Program, work together with other facilities and agencies to enhance our knowledge of and future prediction of space weather?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

December 7, 2017

Reply to Attn of: OLIA/2017-00459f:SWQ

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Ranking Member Bera to Mr. David Schurr resulting from the October 4, 2017, hearing, ***"Powering Exploration: An Update on Radioisotope Production and Lessons Learned from Cassini."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: Ranking Member Ami Bera

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Powering Exploration: An Update on Radioisotope Production and Lessons Learned from Cassini"

Mr. David Schurr, Deputy Director, Planetary Science Division, NASA

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

QUESTION 1:

The Government Accountability Office (GAO), in its report, "*Space Exploration: DOE Could Improve Planning and Communication Related to Plutonium-238 and Radioisotope Power Systems Production Challenges*", notes that NASA had earlier planned to use a dynamic RPS design, such as the Advanced Stirling Radioisotope Generator (ASRG), for future missions and was funding ASRG development work until 2013. The report also indicates that NASA plans to investigate in 2018 dynamic power conversion systems once again.

QUESTION 1a:

What, specifically, are NASA's plans for work on power conversion systems?

ANSWER 1a:

NASA conducts basic and applied energy conversion research and development to advance state-of-the-art performance in heat to electrical energy conversion. Both static and dynamic energy conversion technology development projects are underway at this time to support potential future power systems.

QUESTION 1b:

Did NASA conduct a cost benefit analysis to inform its previous decision on the benefits of continuing ASRG development versus the long-term costs of not continuing that work?

ANSWER 1b:

No, the decision was made as a result of projected cost increases for the ASRG development project at a time when the NASA Planetary Science budget was being significantly reduced. The budget could not support continuing the work, and sufficient technology issues remained to be resolved, with potential future cost increases.

QUESTION 2:

The GAO report referenced above breaks-down NASA's current, annual funding to DOE for Pu-238 production, Radioisotope Power System (RPS) fabrication, and RPS infrastructure sustainment. Does NASA anticipate sustaining all of these activities at the current funding levels over the next budget horizon (FY19-24)?

ANSWER 2:

Yes - Since FY 2011, NASA has funded the costs of reestablishing the Pu-238 production capability. In addition, beginning with NASA's FY 2014 appropriation, the responsibility for funding DOE's existing RPS infrastructure maintenance and production operations is allocated to NASA. The budget for all of these activities is sustained in the latest President's budget.

QUESTION 2a:

What is DOE currently funding for each of these efforts?

ANSWER 2a:

As mentioned in answer 2, NASA has funded the costs of reestablishing the Pu-238 production capability since FY 2011, and funding the production operations.

QUESTION 3:

When do you estimate DOE will be able to meet NASA's annual production requirement of 1.5 kilograms of Pu-238 per year and what is the confidence level of that projection?

ANSWER 3:

The current plan calls for full-rate production of 1.5 kg of heat source plutonium dioxide (HS-PuO2) per year (on average) by 2025. As processes are scaled up from the initial demonstrations (now completed), an interim production rate of 400 grams per year of HS-PuO2 is expected to occur beginning in 2019. While no specific confidence level is specified, this progressive demonstration and ramping up of capacity provide a high degree of confidence early-on that the 2025 goal can be met.

QUESTION 3a:

What is the basis for the confidence level?

ANSWER 3a:

As mentioned in question 3, no specific confidence level is specified; however, progress to date provides a high degree of confidence that the goals can be met. For example, the end-to-end production process has been demonstrated, culminating in some new fuel being included in two of the flight fueled clads for the upcoming Mars 2020 RPS. In addition, plutonium production scale up efforts are on track. Automation equipment to manufacture more targets more expeditiously has been delivered and is being installed for use in 2018. Target irradiations, using the proven capabilities of the High Flux Isotope Reactor (HFIR) continue, and will increase as more targets are manufactured.

QUESTION 3b:

How does the fact that DOE will not have an implementation plan for the Department's management approach for Pu-238 and RPS production until September 2018 and an assessment of challenges to Pu-238 production until 2019 affect NASA's confidence level?

ANSWER 3b:

NASA and DOE meet monthly to review progress in the Pu-238 project, to stay aware of progress while DOE finishes developing their implementation plan. Maintaining open and regular communications allows NASA to remain confident of DOE's ability to meet our objectives.

DOE priority for NASA is focused on executing the Mars 2020 fabrication and fueling campaign in 2018. After this critical objective is completed, DOE and NASA have agreed to transition the delivery of RPS fueled clads from a mission-driven approach to a constant-rate production (CRP) strategy. Applying the CRP strategy affords both agencies the ability to improve the reliability and predictability to deliver RPS solutions in support of NASA exploration missions. CRP establishes clear deliverables for the annual average production rates for new HS-PuO_2 and heat sources manufactured into their fueled clads across the DOE supply chain.

The 2018 implementation plan is an integration of the total supply chain, bringing together both the plutonium supply and the subsequent fueled clad production capabilities of DOE into a single approach, rather than them being separately managed. In addition to completing the Mars 2020 fueling, the HS-PuO_2 interim production scale-up will have matured sufficiently to enable CRP with confidence.

This combination of approaches increases NASA's confidence of DOE supplying the future heat sources for NASA's envisioned planetary exploration missions into the 2030s.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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October 20, 2017

Mr. David Schurr
Deputy Director
Planetary Science Division
National Aeronautics and
Space Administration
300 E Street SW
Washington, D.C. 20546

Dear Mr. Schurr,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the October 4, 2017, hearing titled, *"Powering Exploration: An Update on Radioisotope Production and Lessons Learned from Cassini."*

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than November 3, 2017. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than November 3, 2017.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Brian Babin

Rep. Brian Babin
Subcommittee Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Powering Exploration: An Update on Radioisotope Production and Lessons Learned from Cassini"

Mr. David Schurr, Deputy Director, Planetary Science Division, NASA

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

1. The Government Accountability Office (GAO), in its report, "*Space Exploration: DOE Could Improve Planning and Communication Related to Plutonium-238 and Radioisotope Power Systems Production Challenges*", notes that NASA had earlier planned to use a dynamic RPS design, such as the Advanced Stirling Radioisotope Generator (ASRG), for future missions and was funding ASRG development work until 2013. The report also indicates that NASA plans to investigate in 2018 dynamic power conversion systems once again.
    a. What, specifically, are NASA's plans for work on power conversion systems?
    b. Did NASA conduct a cost benefit analysis to inform its previous decision on the benefits of continuing ASRG development versus the long-term costs of not continuing that work?
2. The GAO report referenced above breaks-down NASA's current, annual funding to DOE for Pu-238 production, Radioisotope Power System (RPS) fabrication, and RPS infrastructure sustainment. Does NASA anticipate sustaining all of these activities at the current funding levels over the next budget horizon (FY19-24)?
    a. What is DOE currently funding for each of these efforts?
3. When do you estimate DOE will be able to meet NASA's annual production requirement of 1.5 kilograms of Pu-238 per year and what is the confidence level of that projection?
    a. What is the basis for the confidence level?
    b. How does the fact that DOE will not have an implementation plan for the Department's management approach for Pu-238 and RPS production until September 2018 and an assessment of challenges to Pu-238 production until 2019 affect NASA's confidence level?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

January 12, 2018

Reply to Attn of: OLIA/2017-00617f:SWQ

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed is material requested for the record and responses to written questions submitted by Ranking Member Bera, Representatives Brooks, Foster, and Posey to Mr. William Gerstenmaier resulting from the November 9, 2017, hearing, ***"An Update on NASA Exploration Systems Development."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: The Honorable Ami Bera, Ranking Member

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Exploration Systems Development"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, NASA

Questions submitted by Ranking Member Ami Bera,

House Committee on Science, Space, and Technology

Question 1:

In your prepared statement you state that "*While NASA's review shows an EM-1 launch date of June 2020 is possible, the Agency is managing to December 2019.*"

Question 1a:

Are NASA and contractor management and personnel all working to the December 2019 launch date, meaning that all schedules and tests must be completed within timeframes predicated on making that December 2019 date? How is NASA ensuring that its efforts to meet the manage-to-date not be perceived by its workforce as causing unhealthy schedule pressure?

Answer 1a:

NASA and its contractor partners are working to the December 2019 launch date for Exploration Mission-1 (EM-1). The majority of work on NASA's new deep space exploration systems is on track. To address schedule risks identified in the review, NASA established new production performance milestones for the SLS Core Stage to increase confidence for future hardware builds. NASA and its contractors are supporting the European Space Agency's (ESA) efforts to optimize build plans for schedule flexibility if sub-contractor deliveries for the European Service Module (ESM) are late. The 2019 launch date target is intended to keep the teams focused and moving forward with a sense of urgency. However, NASA also recognizes that the Programs are carrying four to six months of schedule risk associated with first-time production and operations. NASA will continue to assess progress against the December 2019 planning date.

Question 1b:

What assumptions did NASA use to establish the December 2019 date? What would be the impact on meeting the December 2019 date should those assumptions need adjustment in the future?

Answer 1b:

Among the key assumptions behind the December 2019 launch date are those that affect the enterprise "critical paths" that are the schedule drivers pacing other exploration activities relating to the first-time production of elements for the Space Launch System (SLS), Orion crew vehicle, and Exploration Ground Systems (EGS) and the integration of those elements. Key assumptions for these critical paths include:

- Delivery of the Orion ESM to the Operations and Checkout facility at the Kennedy Space Center (KSC) in late spring / early summer of 2018 for integration with the Orion Crew Module and the start of integrated testing;
- Delivery of the SLS Core Stage to the Stennis Space Center in December 2018 for the start of green run testing, followed by delivery to KSC in June 2019 for stacking;
- Completion of spaceport command and control software testing and checkout in February 2019.

Potential challenges that impact one or more of the elements might delay this integration and testing plan.

Question 1c:

What remaining technical, production, and integration issues have the potential to negatively impact NASA's latest EM-1 launch date estimate? What are some ways by which you plan on addressing them?

Answer 1c:

While most hardware development and activities for these systems are on track with multiple months of margin, the Agency's technical management team remains focused on the "critical paths" of ESM delivery, the SLS Core Stage development, and spaceport command and control software development. The ESM and Core Stage issues largely involve challenges related to first-time design and assembly.

NASA is working closely with ESA to ensure delivery of the ESM in late spring/early summer 2018. This cooperation is focused on quickly solving technical issues as they arise, reducing schedule dependencies, and generally finding efficiencies through the integrated schedule. For example, NASA is working with U.S. vendors supplying hardware to Airbus (prime contractor for the ESM) to resolve technical issues seen in component-level testing; providing additional technician support to accelerate wire harness building, installation, and testing; and assessing the overall Orion integration schedule to provide opportunities for integrating ESM components after the ESM is delivered to KSC.

NASA and Boeing have implemented a number of changes already having a positive impact on core stage production. For example, senior Boeing management is very engaged in monitoring program progress and quickly addressing challenges as soon as they occur. Boeing has increased on-site production labor working three shifts during the week and two shifts on weekends. Boeing has also set up a dedicated core stage production operations center with integration managers coordinating daily operations, as well as a dedicated green run manager to ready the first core stage for testing at the Stennis Space Center in Mississippi starting approximately one year prior to launch.

NASA has moved additional engineering staff to Michoud Assembly Facility to reduce the cycle time for solving manufacturing problems in real time. Overall, NASA and Boeing are working methodically through issues that are not unexpected during the first-time production of such a large and complex piece of aerospace hardware.

Question 2:

Regarding NASA's establishment of the December 2019 manage-to-date:

Question 2a:

Is that the date to which Congress should hold NASA accountable? How will NASA communicate both (1) the status of risks as it moves towards the manage-to-launch date of December 2019 and (2) the ongoing impacts that resolution of those risks are having on the achievability of the December 2019 date?

Answer 2a:

NASA is managing to the December 2019 EM-1 date, which is aggressive – with up to six months of additional schedule risk – but achievable. It is important to understand that in developing and integrating the Orion crew spacecraft, SLS heavy-lift launch vehicle, and extensive ground-based systems to support them, we are laying the foundation for a sustainable infrastructure for human deep space exploration for decades to come – one that will support missions to a variety of destinations, including the Moon and Mars. Thus, while EM-1 itself is important, it also represents the first in an ongoing continuum of Exploration Missions.

NASA will provide formal notification to Congress under Section 103 of the NASA Authorization Act of 2005 (P.L. 109-155).

Question 2b:

More generally, what indicators and milestones should Congress use to measure progress on the SLS, Orion, and EGS programs?

Answer 2b:

As noted in the response to Question #1b and #1c, above, NASA is particularly focused on ESM delivery, the SLS Core Stage development, and spaceport command and control software development.

Question 3:

In a recently released report, the NASA Inspector General said "the biggest challenge facing Orion for EM-1 is delivery of the European Service Module." Do you agree with that assessment? Can you describe the challenges that have caused delays to the delivery of the European Service Module? Have the difficulties experienced in designing and developing European Service Module informed NASA on how future international and commercial partner participation in human space exploration programs should be structured? What, if any, changes have been made to ensure that the Service Module for EM-2 does not encounter similar challenges?

Answer 3:

The critical path items at this point for EM-1 include the projected delivery of Orion's ESM, SLS Core Stage development, spaceport command and control software development. Challenges with the ESM delivery for EM-1 are largely related to issues involving first time design and assembly. Coordination with ESA on ESM assembly, integration, and testing is improving, and NASA has increased involvement in resolving domestic and international vendor technical and schedule performance issues.

NASA is planning on ESA supplying the service module for Orion on future deep space missions. The relationship we have built with ESA working on EM-1 will serve to strengthen our joint efforts moving forward on EM-2. Furthermore, we are working with both domestic and international partners to solve the great challenges of deep space exploration, including studying lunar activity. We will build on the partnerships we have established with both industry and international space agencies in low-Earth orbit as we move humans farther into the solar system.

Question 4:

Regarding the Vice President's recent direction to conduct human lunar exploration:

Question 4a:

How would a return to the Moon, including potentially establishing a human presence there, impact the goal of sending humans to Mars in the 2030s, as directed in the 2017 NASA Transition Act?

Answer 4a:

A NASA return to the Moon for long-term exploration and utilization will enable building and testing systems needed for other challenging missions to deep space destinations, including Mars. The details of NASA's lunar missions are currently being developed and will be reflected in future budget requests.

Question 4b:

When will NASA inform Congress of (1) the total budgetary impact of adding lunar surface activities the agency's exploration program and (2) how much funding will need to be added to the HEO budget on an annual basis to pursue both the Moon and humans to Mars?

Answer 4b:

Please see response to Question #4a, above.

Question 5:

While many people may naturally tend to focus on the EM-1 launch date, I understand that the factors surrounding that launch date involve establishing a development, production, and launch capability for NASA's human exploration missions for decades to come.

Question 5a:

What key challenges is NASA facing during the development of systems like SLS/Orion/EGS in establishing production processes for the first time and what will it take to achieve a production capacity capable of conducting a sustained human space exploration program? When do you anticipate NASA will have that capability in place and what do you estimate the average annual launch rate will be at that juncture?

Answer 5a:

The SLS and Orion programs have made extensive investments in advanced manufacturing techniques like reaction friction stir welding and additive manufacturing, investments to help achieve a production capacity capable of conducting a sustained human space exploration program.

One example of a key challenge NASA has overcome during EM-1 has been the development of friction stir welding techniques and equipment used in the manufacture of SLS. NASA and Boeing have done extensive work to develop weld parameters and processes for making the first-of-their-kind large propellant tanks, and engineers working on the rocket have learned a great deal from meeting challenges ranging from the precise alignment of weld machines to addressing the fact that tiny threads on welding pins affect weld strength. Producing the SLS' propellant tanks has pushed the state-of-the-art for self-reacting friction stir welding of thicker materials. This is the first time robotic self-reacting friction stir weld technology has built such large rocket parts with thicker joints. NASA and Boeing have learned a great deal by working through processes to get weld parameters for the large fuel tanks adjusted to produce high-quality welds that can withstand the extreme forces of launch and spaceflight.

SLS, Orion, and exploration ground systems are being designed to be capable of supporting a long-term flight rate of one per year with a surge capability of three per year. The actual cadence of missions beyond EM-2 will be defined based on mission needs, available resources, and operational costs. Reducing production and operations costs will be critical for enabling an ambitious exploration program.

Question 5b:

What have NASA and its SLS and Orion contractors done to incorporate efficiencies into production processes?

Answer 5b:

NASA has assessed the results from a recent affordability Request for Information and will work with industry to reduce overall costs once SLS and ground systems enter the production and operations phase.

As one option, NASA will assess whether some elements may be reused and if reuse will lead to reduced costs. For example, NASA is assessing the potential reuse of avionics boxes on the Orion Crew Module (and possibly even the pressure vessel of the Crew Module itself). That assessment will take into account the demonstrated condition of that hardware on EM-1 and subsequent flights, after the hardware has been through long-duration missions in the hostile environment of deep space.

SLS leverages over a half-century of experience with launch vehicles, including Saturn and Space Shuttle, along with advancements in technology since that time, including model-based engineering, additive manufacturing, high-fidelity computational fluid dynamics capabilities, new composite materials and production techniques, and large-scale self-reaction friction stir welding. Additionally, initial flight units use components already owned from the Space Shuttle, such as RS-25 engines and boosters. More efficient methods are under development for manufacturing these components, including new NASA investment in expendable RS-25 engines for the SLS Core Stage with the goal of achieving a lower per-unit cost than the original reusable RS-25s used as the Space Shuttle Main Engines. The Agency continues to identify affordability strategies for missions beyond EM-2. Reducing overall costs of the systems will be critical to achieving a successful and sustainable exploration capability.

For ground systems, the launch and flight support infrastructure at KSC will be able to provide a more flexible, affordable, and responsive national launch capability compared to prior approaches.

Question 5c:

To what extent will establishing a development, production, and launch capability have benefits for other stakeholders, including commercial and international partners? If so, will they share the costs?

Answer 5c:

As noted in the response to Question #5a, above, the SLS and Orion programs have made extensive investments in advanced manufacturing techniques like reaction friction stir welding and additive manufacturing, investments which have helped to position the nation and U.S. companies as world leaders in this critical technological area. The specifics of potential benefits to commercial and international partners, as well as any cost-sharing plans, would depend on the details of partner proposals.

Question 5d:

How is NASA applying lessons learned on fabricating EM-1 to its work on EM-2? To what extent have these lessons affected the EM-2 production process?

Answer 5d:

Please see response to Question #5a, above, regarding friction stir welding as an example of work on EM-1 that is being refined as NASA moves forward to EM-2. As NASA and its contractor teams overcome first-time production and operations issues and gain experience with new manufacturing processes, the Agency expects further refinements that will benefit future production.

Question 6:

How important is the role of component and system suppliers in meeting SLS, Orion, and ground system production milestones? What has been your experience with suppliers in preparing for EM-1? What, if any, changes are needed to ensure that the supply chain is working smoothly toward making maximum progress on exploration development systems?

Answer 6:

Component and system suppliers are critical to the development of NASA's exploration systems, and the Agency's experience with such subcontractors has demonstrated their dedication to the mission. As the U.S. aerospace industrial base has evolved in recent decades, the overall number of suppliers of certain highly specialized items used in the SLS and Orion systems have been reduced, and certain areas of expertise have been de-emphasized. NASA is working with its industry partners to ensure that the supply chain will work smoothly to provide long-term production support, and the teams are gaining important experience as they support EM-1 and beyond.

Question 7:

Both the NASA Inspector General and the GAO have expressed concern about the limited amount of cost reserves available to address issues as they arise in exploration systems development. The IG states, "*according to guidance developed at Marshall Space Flight Center (Marshall), the standard monetary reserve for a program such as the SLS should be between 10 and 30 percent during development.*"

Question 7a:

How much cost reserve do the SLS, Orion, and EGS programs currently have as a percentage of the development budget? How do you see this changing in the future?

Answer 7a:

While NASA is not managing based upon percentages of reserves, the three programs do have reserves spread across their life cycles. Through the budget horizon through 2023, the following are being bookkept as reserves within the respective program offices:

- SLS: approximately 3 percent from FY 2018 through FY 2023
- Orion: approximately 6 percent from FY 2018 through FY 2023
- EGS: approximately 6 percent from FY 2018 through FY 2023

These reserves (along with the updates NASA has made to its approach to managing systems engineering and integration, and an increased emphasis on production performance for the Orion

ESM, SLS Core Stage, and spaceport command and control software development) give NASA confidence to deliver EM-1 and to continue evolving the overall enterprise capability.

Question 7b:

Is maintaining a 10 to 30 percent cost reserve a best practice NASA should follow in the development of systems like SLS, Orion, and EGS? If not, what is the optimal level of reserves?

Answer 7b:

While some NASA Centers emphasize the use of a percentage of total life cycle costs as reserves, this best practice was developed for one-off missions such as the development of a science satellite or planetary mission. However, SLS, Orion, and EGS are not one-off missions. NASA manages the SLS, Orion, and EGS programs as an evolving and multi-mission capability with workforce and costs being divided among several different missions and objectives.. As a result, there are many tools (in addition to holding cost reserves) which can be utilized to meet program goals, such as manifest and schedule management (including phasing the sequence of missions); evolution and upgrade management (including phasing of when new system capabilities are needed); contract management (including the phasing of contract awards); workforce management; and management of cost reserves. NASA has decades of experience (including most recently with Space Shuttle and the International Space Station) balancing the unknowns of an ongoing spaceflight capability within an annual topline budget using such a combination of tools. .

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Exploration Systems Development"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, NASA

Questions submitted by Representative Mo Brooks,

House Committee on Science, Space, and Technology

Question 1:

Nuclear Thermal Propulsion is one of the more promising areas that NASA is working on to help speed transit time and limit radiation exposure for astronauts lengthy deep space missions. What is the current timeline for the development of technology and when can we expect it to become operational for deep space missions?

Answer 1:

In FY 2016, the NASA's Space Technology Mission Directorate (STMD) initiated development of foundational technologies and began studies to advance nuclear thermal propulsion systems that face numerous challenges to develop, but could ultimately provide a rapid and architecturally robust in-space transportation capability. This three-year project is taking the initial key steps to explore how to enable more efficient spaceflight by developing and testing low-enriched-uranium fuel elements to support a potential future nuclear thermal propulsion system.

The overarching goal for this three-year plan is to assess the technical feasibility and affordability of nuclear thermal propulsion for faster and more flexible transport on deep space exploration missions. The resulting analysis will close the gaps in our current knowledge of low-enriched-uranium based systems, and allow NASA to make informed decisions on Mars exploration architectures with credible cost estimates and a higher level of schedule confidence.

However, high cost, long development times, and a lack of utility for US commercial providers are preventing nuclear propulsion from being considered in NASA's near-term exploration plans.

Question 2:

The Marshall Space Flight Center in my district has been doing some exciting work on Nuclear Thermal Propulsion technology over the years. Can you elaborate a little on if you support the plan to complete a ground demonstration project in the next few years?

Answer 2:

NASA has made initial investments through a three year project funded within Space Technology's Game Changing Development Program. As noted, this project is led by NASA's Marshall Space Flight Center (MSFC) with contracts to Dynetics, Aerojet Rocketdyne, BWX

Technologies, Analytical Mechanics Associates, and with NASA's Stennis Space Center (SSC), NASA's Glenn Research Center (GRC), and the Department of Energy (DOE) as collaborating partners. At the conclusion of this three-year activity, a determination will be made whether to continue to pursue development of the nuclear thermal propulsion technology.

Dependent on the outcome of the initial three year effort, subsequent steps might include completing the design and building the reactor and engine, culminating in a full-scale, full-power engine test. During the course of these efforts, a ground test approach for capturing the exhaust would need to be developed and implemented. Additionally, long-term space storage of liquid hydrogen would need to be demonstrated, utilizing cryogenic fluid management (CFM) technologies that are currently being developed through Space Technology's eCryo project. The last major step would be to design and build the space propulsion stage that would utilize the NTP system and the CFM technologies.

The Agency is working to reduce technology barriers for potential future applications. However, the total cost of the full scale, full power engine test along with the development of an operational NTP system, would be significant barrier in considering NTP for future human exploration missions.

Question 3:

How can NASA lay the groundwork for this potentially innovative technology with greater foresight and ambition toward deep space exploration?

Answer 3:

NASA's near term objective is to find an affordable approach for the development of NTP systems using Low Enriched Uranium, enabling the participation of industry and/or academia by lessening the burden of security requirements on the system and avoiding building new government infrastructure. NASA hopes to leverage commercial manufacturing techniques, infrastructure and business base to defray costs. The Agency faces 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;
- Devising a safe and affordable engine ground test and qualification approach; and,
- Maturing reactor and engine system designs.

As noted above, STMD initiated a technology assessment and maturation project in FY 2016 to determine whether a design based on low enriched uranium (LEU) fuel elements could enable an affordable nuclear thermal propulsion system. Major tasks for the three-year effort include:

- Design, fabrication, and testing of ceramic-metallic composite (cermet) fuel elements;
- Performing feasibility analysis and detailed cost analysis of an LEU-based engine;
- Developing a safe and affordable nuclear thermal engine ground testing approach; and

- Performing a detailed cost analysis for the full development effort leading to the first flight system.

In addition, the research efforts mentioned above on long-term storage of cryogenic hydrogen propellant is an essential part of the nuclear thermal propulsion research activities. Cryogenic fluid management (CFM) technologies are currently being developed and tested on the ground, including Space Technology's eCryo project. eCryo is conducting a large-scale ground demonstration of liquid hydrogen storage with very low boil off of the propellant.

These activities are the essential first step in determining the applicability for future exploration.

Question 4:

Is it true that nuclear thermal propulsion technology can dramatically increase the safety for astronauts on a future trip to Mars?

Answer 4:

Nuclear thermal propulsion systems face numerous challenges to develop, but could ultimately provide a rapid and architecturally robust in-space transportation capability. The extremely high energy density of nuclear reactions makes them attractive conceptually as an energy source for propulsion systems. With hydrogen as the propellant, exhaust velocities for nuclear thermal propulsion can be more than a factor of two greater than the highest performing chemical propulsion systems. By comparing that increase with the high thrust values associated with chemical rocket engines, it is estimated that a nuclear thermal propulsion system could reduce the round-trip transit time to Mars by 25 percent or more, and also provide increased flexibility in Earth departure and return trip scheduling. However, as a new and complex technology, it will take substantial analysis, ground facilities testing, and on-orbit performance to fully match the safety reliability of existing chemical propulsion systems.

Question 5:

As we march forward making the Space Launch System and Orion the system that will send humans into deep space, commercial companies are working to provide human access to low earth orbit. Safety must remain the number one priority in all these programs. Do you have any concerns with the Falcon 9 platform given the recent failure of a Merlin D engine?

Answer 5:

SpaceX continues to make good progress towards launching crew to the International Space Station (ISS) in 2018, and incorporates lessons learned from test failures. SpaceX notified NASA of the recent Merlin engine failure. The company is investigating internally and keeping NASA fully informed of the team's progress. NASA's insight into the SpaceX and Boeing Commercial Crew efforts is helping to ensure that our astronauts will have safe, reliable, domestic transportation to ISS in the years ahead.

Question 6:

Does NASA plan to provide an incident report for all recent failures to Congress?

Answer 6:

NASA briefed its findings on the SpaceX-7 launch failure to Congressional staff in January 2016. The Agency is in the process of producing a Public Summary Report for the NASA Launch Services Program (LSP)-led Independent Review Team investigation of the SpaceX-7 launch failure. This report is currently going through the appropriate reviews to ensure that International Traffic in Arms Regulations (ITAR)/Export Controlled, and Proprietary information is not included.

NASA is still active with its independent review of the SpaceX Pad Anomaly that occurred on Sept. 1, 2016. The independent review's findings will be captured in a briefing to the Agency's Flight Planning Board. NASA is happy to brief the interested Congressional Members and/or staff on our findings once the investigation is complete. This failure is being used as the basis for analysis and design of the composite overwrap pressure vessel planned for use on the Falcon 9 Block 5 launch vehicle planned for commercial crew flights. Procedural changes are being implemented by SpaceX to prevent problems similar to this anomaly for commercial cargo flights. No formal written report or public summary is planned. For further details on the event and specific lessons learned, NASA recommends contacting SpaceX.

Question 7:

What are the indemnification coverage steps that NASA has in place with regards to commercial companies?

Answer 7:

The procedure for a contractor to request indemnification for third-party liability and the process for NASA to consider and analyze such a request is set forth in Part 50 of the Federal Acquisition Regulation (FAR) and Part 1850 of the NASA FAR Supplement (NFS). This process is the same for any contractor, regardless of the type of contract or whether a company is "commercial". However, this process for requesting and granting indemnification is applicable only if NASA has specific statutory authority to indemnify the contractor under the particular circumstances of the request. Among several factual bases required for NASA or any Federal agency to indemnify a contractor is that the work required to be performed under the contract must involve unusually hazardous risk for which commercial insurance is unavailable. Such legal authorities are narrowly construed because the Government's indemnification of a contractor for third-party liabilities represents an extraordinary contractual re-allocation of risk and responsibility among the parties to a contract.

Government contract law and regulations ordinarily require that contractors will be responsible for the risks resulting from their own work, and accordingly, contractors protect themselves from resulting liability with a financial protection program that includes commercial insurance. In a few extraordinary circumstances, Congress has recognized that certain work performed by a contractor entails unusually hazardous risks for which commercial insurance is not available and as such Congress has authorized, through a few very specific legal authorities such as Public Law 85-804 and the Price Anderson Act Amendments, some agencies to relieve the contractor with respect to assuming liability resulting from the contractor's performance of that work. Specifically with respect to "commercial" launch services providers, under the

Commercial Space Launch Act (CSLA), the Federal Aviation Administration (FAA) handles indemnification for launches conducted under a FAA-issued commercial license.

Question 8:

Is NASA able to offer indemnification to Nuclear Thermal Propulsion technology? If not, why not?

Answer 8:

NASA is currently exploring options for indemnification that would not require additional Congressional authority. Should new or modified authority be necessary, the Agency will notify the appropriate Congressional Committees.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Exploration Systems Development"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, NASA

Questions submitted by Representative Bill Posey, House Committee on Science, Space, and Technology

Question 1:

When it comes to space, the unimaginable has often become the imaginable and the achievable, especially when we commit to long-term research, development and strategies. As we hone in on making manned mission to Mars a reality and other lengthy missions — manned or unmanned — I am intrigued by the potential for resources available in space to be used as fuel in space. If realized, this potential will lighten payloads and extend the range and duration of our missions. As such, would you comment on NASA's strategic view or long-term architecture for in-space refueling? Moreover, in NASA's exploration plan will NASA evaluate the value and potential for utilizing in-space resources like those found on asteroids?

Answer 1:

The farther humans go into deep space, the more important it will be to produce propellants and life support system consumables with in-situ resource utilization (ISRU). Some of the most promising space-based commodities that could enable substantial reductions in the mass, cost, and risk of human space exploration include oxygen, water, and methane. These products are critical for sustaining crew and for space propulsion and power systems. They may be derived from space resources such as the carbon dioxide-rich Mars atmosphere and water deposits based in lunar, Mars, and asteroid soil (also called regolith). Deposits of water and other useful volatiles, which are substances that evaporate easily at moderate temperatures, are not yet fully characterized, and work remains to understand their accessibility. Accordingly, NASA's priorities for advancing ISRU include exploring volatile deposits at destinations of interest so resource potential can be determined, and extraction and utilization equipment can be properly designed.

In FY 2018, NASA is pursuing several activities that will advance ISRU technology. NASA is developing the Mars Oxygen ISRU Experiment (MOXIE) for the Mars 2020 rover that will demonstrate the production of oxygen from the Mars atmosphere. In December 2017, NASA issued a Broad Agency Announcement (BAA) to solicit proposals for public-private partnerships to develop and test component technologies and subsystems for ISRU.

For further information on the BAA, please see:

https://www.nasa.gov/feature/nasa-seeks-commercial-solutions-to-harvest-space-resources

For further information on ISRU, please see:

https://www.nasa.gov/isru

The Space Technology Mission Directorate (STMD) is developing capabilities for in-space propulsion, including cryogenic propellant storage, power generation and energy storage, and on-orbit refueling. For example, cryogenic fluid management technologies are currently being developed and tested on the ground, through Space Technology's eCryo project. eCryo is conducting a large-scale ground demonstration of liquid hydrogen storage with very low boil off of the propellant. Managing cryogenic fluids and minimizing boil-off of cryogenic propellants on long duration missions is a critical capability needed to enable high-performance in-space propulsion stages, as well as on orbit refueling.

For information about Space Technology, please see:

https://www.nasa.gov/directorates/spacetech/home/index.html

Question 2:

In September, this Subcommittee held a hearing with Mr. Jason Crusan on your staff about NASA's work with robotic lunar lander companies, like on the Lunar CATALYST program, which I understand NASA just extended for an additional two years. During the hearing, Mr. Crusan said:

"The agency is currently assessing possible robotic mission concepts, acquisition approaches, and associated payloads for a potential series of lunar cargo missions to the surface of the Moon starting as early as 2018," and "the agency is interested in assessing the availability of commercial delivery services from earth to the lunar surface as early as next fiscal year."

As you know, Chairman Culberson and the Commerce-Justice-Science Appropriations Subcommittee included $30M for Lunar Lander demonstration missions in the FY 2018 Appropriations bill. Based on Mr. Crusan's testimony and the Appropriations Subcommittee support, how does NASA plan to leverage robotic lunar lander missions starting in FY 2018, especially as the Administration is focusing on Lunar exploration opportunities?

Answer 2:

NASA is supporting the development of commercial lunar exploration. In 2014, NASA introduced Lunar CATALYST (Lunar Cargo Transportation and Landing by Soft Touchdown) and entered into competitively awarded partnerships with three U.S. firms (Astrobotic Technologies, Masten Space Systems, and Moon Express) to provide in-kind support to develop commercial lunar robotic landing capabilities. NASA is providing engineering expertise, hardware and software, and test facilities to these companies. The purpose of the 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. Initial flights of commercial lunar landers may begin as early as 2018, and as a result one or more of these companies will be able to market lunar payload delivery services for small instruments and technology demonstrations. Commercial lunar transportation capabilities could support science and exploration objectives such as sample returns, geophysical network deployment, resource utilization, and technology advancements.

The details of NASA's lunar missions are currently being developed and will be reflected in future budget requests.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Exploration Systems Development"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, NASA

Questions submitted by Representative Bill Foster, House Committee on Science, Space, and Technology

Question 1:

The Apollo lunar landing program cost $24B in 1960s dollars over 10 years. That means NASA set aside nearly 4 percent of U.S. GDP to get to the moon. Today, 50 years later, NASA's budget is about $19B per year which is less than one tenth of one percent of GDP.

In order to begin our political and fiscal planning for a mission to Mars, it is imperative to have an estimate of what it would cost to meet this goal. Mr. Gerstenmaier, do you have what you believe is a realistic upper and lower limit to the cost for getting to Mars? If so, please share that estimate with this Subcommittee.

Answer 1:

Between 1960 and 1973, the Apollo Program accounted for approximately 0.9 percent of total Federal outlays (peaking at approximately 2.2 percent of Federal outlays in 1966) and approximately 0.1 percent of the U.S. gross domestic product. As NASA learns from initial missions using SLS and Orion and develops new technologies to make exploration more affordable, the Agency will formulate cost and schedule details of future goals and hardware, and this analysis will be reflected in future budget requests. NASA is planning toward roughly today's budget levels.

Material requested for the record on page 59, line 1380, by Representative Higgins during the November 9, 2017 hearing at which Mr. William Gerstenmaier testified.

Provide information about the large lava tubes on the Moon.

Answer:

NASA's Lunar Reconnaissance Orbiter (LRO) and Gravity Recovery and Interior Laboratory (GRAIL) data supported the attached analysis, "The Structural Stability of Lunar Lava Tubes," by D.M. Blair, et al., from the journal *Icarus*, published by Elsevier, Inc.; the attached article provides the requested information on lava tubes on the Moon.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

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November 27, 2017

Mr. William Gerstenmaier
Associate Administrator
Human Exploration and Operations Directorate
National Aeronautics and
Space Administration (NASA)
300 E Street SW
Washington, DC 20546

Dear Mr. Gerstenmaier,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the November 9, 2017, hearing titled, *"An Update on NASA Exploration Systems Development."*

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than December 11, 2017. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than December 11, 2017.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Rep. Brian Babin
Subcommittee Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Exploration Systems Development"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, NASA

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

1. In your prepared statement you state that "*While NASA's review shows an EM-1 launch date of June 2020 is possible, the Agency is managing to December 2019.*"

    a. Are NASA and contractor management and personnel all working to the December 2019 launch date, meaning that all schedules and tests must be completed within timeframes predicated on making that December 2019 date? How is NASA ensuring that its efforts to meet the manage-to-date not be perceived by its workforce as causing unhealthy schedule pressure?

    b. What assumptions did NASA use to establish the December 2019 date? What would be the impact on meeting the December 2019 date should those assumptions need adjustment in the future?

    c. What remaining technical, production, and integration issues have the potential to negatively impact NASA's latest EM-1 launch date estimate? What are some ways by which you plan on addressing them?

2. Regarding NASA's establishment of the December 2019 manage-to-date:

    a. Is that the date to which Congress should hold NASA accountable? How will NASA communicate both (1) the status of risks as it moves towards the manage-to-launch date of December 2019 and (2) the ongoing impacts that resolution of those risks are having on the achievability of the December 2019 date?

    b. More generally, what indicators and milestones should Congress use to measure progress on the SLS, Orion, and EGS programs?

3. In a recently released report, the NASA Inspector General said "the biggest challenge facing Orion for EM-1 is delivery of the European Service Module." Do you agree with that assessment? Can you describe the challenges that have caused delays to the delivery of the European Service Module? Have the difficulties experienced in designing and developing European Service Module informed NASA on how future international and commercial partner participation in human space exploration programs should be structured? What, if any, changes have been made to ensure that the Service Module for EM-2 does not encounter similar challenges?

4. Regarding the Vice President's recent direction to conduct human lunar exploration:

    a. How would a return to the Moon, including potentially establishing a human presence there, impact the goal of sending humans to Mars in the 2030s, as directed in the 2017 NASA Transition Act?

    b. When will NASA inform Congress of (1) the total budgetary impact of adding lunar surface activities the agency's exploration program and (2) how much funding will need to be added to the HEO budget on an annual basis to pursue both the Moon and humans to Mars?

5. While many people may naturally tend to focus on the EM-1 launch date, I understand that the factors surrounding that launch date involve establishing a development, production, and launch capability for NASA's human exploration missions for decades to come.

    a. What key challenges is NASA facing during the development of systems like SLS/Orion/EGS in establishing production processes for the first time and what will it take to achieve a production capacity capable of conducting a sustained human space exploration program? When do you anticipate NASA will have that capability in place and what do you estimate the average annual launch rate will be at that juncture?

    b. What have NASA and its SLS and Orion contractors done to incorporate efficiencies into production processes?

    c. To what extent will establishing a development, production, and launch capability have benefits for other stakeholders, including commercial and international partners? If so, will they share the costs?

    d. How is NASA applying lessons learned on fabricating EM-1 to its work on EM-2? To what extent have these lessons affected the EM-2 production process?

6. How important is the role of component and system suppliers in meeting SLS, Orion, and ground system production milestones? What has been your experience with suppliers in preparing for EM-1? What, if any, changes are needed to ensure that the supply chain is working smoothly toward making maximum progress on exploration development systems?

7. Both the NASA Inspector General and the GAO have expressed concern about the limited amount of cost reserves available to address issues as they arise in exploration systems development. The IG states, "*according to guidance developed at Marshall Space Flight Center (Marshall), the standard monetary reserve for a program such as the SLS should be between 10 and 30 percent during development.*"

    a. How much cost reserve do the SLS, Orion, and EGS programs currently have as a percentage of the development budget? How do you see this changing in the future?

    b. Is maintaining a 10 to 30 percent cost reserve a best practice NASA should follow in the development of systems like SLS, Orion, and EGS? If not, what is the optimal level of reserves?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Exploration Systems Development"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, NASA

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

1. Nuclear Thermal Propulsion is one of the more promising areas that NASA is working on to help speed transit time and limit radiation exposure for astronauts lengthy deep space missions. What is the current timeline for the development of technology and when can we expect it to become operational for deep space missions?

2. The Marshall Space Flight Center in my district has been doing some exciting work on Nuclear Thermal Propulsion technology over the years. Can you elaborate a little on if you support the plan to complete a ground demonstration project in the next few years?

3. How can NASA lay the groundwork for this potentially innovative technology with greater foresight and ambition toward deep space exploration?

4. Is it true that nuclear thermal propulsion technology can dramatically increase the safety for astronauts on a future trip to Mars?

5. As we march forward making the Space Launch System and Orion the system that will send humans into deep space, commercial companies are working to provide human access to low earth orbit. Safety must remain the number one priority in all these programs. Do you have any concerns with the Falcon 9 platform given the recent failure of a Merlin D engine?

6. Does NASA plan to provide an incident report for all recent failures to Congress?

7. What are the indemnification coverage steps that NASA has in place with regards to commercial companies?

8. Is NASA able to offer indemnification to Nuclear Thermal Propulsion technology? If not, why not?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Exploration Systems Development"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, NASA

Questions submitted by Representative Bill Posey, House Committee on Science, Space, and Technology

1. When it comes to space, the unimaginable has often become the imaginable and the achievable, especially when we commit to long-term research, development and strategies. As we hone in on making manned mission to Mars a reality and other lengthy missions — manned or unmanned — I am intrigued by the potential for resources available in space to be used as fuel in space. If realized, this potential will lighten payloads and extend the range and duration of our missions. As such, would you comment on NASA's strategic view or long-term architecture for in-space refueling? Moreover, in NASA's exploration plan will NASA evaluate the value and potential for utilizing in-space resources like those found on asteroids?

2. In September, this Subcommittee held a hearing with Mr. Jason Crusan on your staff about NASA's work with robotic lunar lander companies, like on the Lunar CATALYST program, which I understand NASA just extended for an additional two years.

   During the hearing, Mr. Crusan said:

   "The agency is currently assessing possible robotic mission concepts, acquisition approaches, and associated payloads for a potential series of lunar cargo missions to the surface of the Moon starting as early as 2018," and "the agency is interested in assessing the availability of commercial delivery services from earth to the lunar surface as early as next fiscal year."

   As you know, Chairman Culberson and the Commerce-Justice-Science Appropriations Subcommittee included $30 million for Lunar Lander demonstration missions in the FY2018 Appropriations bill. Based on Mr. Crusan's testimony and the Appropriations Subcommittee support, how does NASA plan to leverage robotic lunar lander missions starting in FY2018, especially as the Administration is focusing on Lunar exploration opportunities?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Exploration Systems Development"

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Directorate, NASA

Questions submitted by Representative Bill Foster, House Committee on Science, Space, and Technology

1. The Apollo lunar landing program cost $24 billion in 1960s dollars over 10 years. That means NASA set aside nearly 4 percent of U.S. GDP to get to the moon. Today, 50 years later, NASA's budget is about $19 billion per year which is less than one tenth of one percent of GDP.

   In order to begin our political and fiscal planning for a mission to Mars, it is imperative to have an estimate of what it would cost to meet this goal. Mr. Gerstenmaier, do you have what you believe is a realistic upper and lower limit to the cost for getting to Mars? If so, please share that estimate with this Subcommittee.

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

December 20, 2017

Reply to Attn of: OLIA/2017-00666/667f:SWQ

The Honorable Darin LaHood
Chairman
Subcommittee on Oversight
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed is the edited transcript, material requested for the record and responses to written questions submitted by Ranking Member Beyer, resulting from the November 14, 2017 hearing, ***"Bolstering the Government's Cybersecurity: A Survey of Compliance with the DHS Directive."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: The Honorable Don Beyer, Ranking Member

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Bolstering the Government's Cybersecurity:
A Survey of Compliance with the DHS Directive"

Ms. Renee Wynn, Chief Information Officer,
National Aeronautics and Space Administration

Questions Submitted by Ranking Member Donald S. Beyer, Jr., Subcommittee on Oversight, House Committee on Science, Space, and Technology

Question 1: **Pre-installed Software on Agency Computers**
During the hearing, in response to questions about federal government computers using Kaspersky Lab software. Ms. Manfra from the Department of Homeland Security stated that of the federal government computers found using Kaspersky Lab software, most were not specifically procured by the respective agencies, but came from bulk hardware purchases with Kaspersky Lab software pre-installed.

Question 1a:

Does your agency ever accept pre-installed software on agency-purchased computers?

Answer 1a:

All Enterprise-managed computers are wiped and the systems are reloaded with a NASA approved software load.

Question 1b:

If so, please indicate the security process the agency uses to minimize the security threat these acquired computers can pose?

Answer 1b:

N/A

Question 1c:

Does the agency have a policy of "wiping" all purchased computers before connecting them to the agency's computer network?

Answer 1c:

All Enterprise-managed systems are wiped and reloaded with a NASA approved software build prior to joining the NASA network as part of the contractor's standard operating procedure to deploy new seats. NASA's policy on desktop standards is currently being updated to formally document this requirement.

Question 2: **Kaspersky Lab Subcomponents on Federal Networks**
According to information on its website, Kaspersky Lab offers software development kits for integration into third party hardware and software. Some Kaspersky Lab products are reportedly used within other companies' hardware products, including those of Cisco, Juniper and Microsoft-though these relationships are not always explicitly disclosed in product information.

Question 2a:

What efforts has your agency taken to insure that Kaspersky Lab software embedded in third-party products is eliminated from federal government systems, as ordered by DHS Binding Operational Directive (BOD) 17-01, issued on September 13, 2017?

Answer 2a:

NASA uses a baseline software suite and core load for its devices to comply with Federal requirements for desktop computers, laptops, and other end user devices. If a system owner requests the installation of software not approved by NASA, the NASA Office of the Chief Information Officer (OCIO) must approve individual instances and accept a level of risk. The NASA CIO has not approved any installations of Kaspersky Lab Products.

To identify and mitigate installations of Kaspersky, whether embedded or not, NASA uses enhanced scanning tools as a part of the DHS Continuous Diagnostics and Mitigation (CDM) program. These tools scan all IT assets and monitor network traffic on systems connected to the Agency network. Manual scans and inquiries at the local level are also performed. As of the response to BOD 17-01 to DHS on October 13, 2017, NASA has identified no active installations of embedded or non-embedded Kaspersky Lab Products.

Additionally, the NASA Office of Procurement (OP) searched Agency and Federal procurement databases to determine if there are documented purchases of said software at NASA during the timeframe of your query. OP searched the Agency's System for Award Management (SAM), the Federal Procurement Data System – Next Generation (FPDS-NG) and records for the NASA Agency Purchase Card Program. OP also searched for records utilizing the NASA IT Security – Enterprise Data Warehouse (ITSEC-EDW) system. The OP found no record of Agency funds being used to purchase individual instances of Kaspersky Lab software.

Question 2b:

Please indicate the number of Kaspersky Lab subcomponents identified in third party hardware or software on your agency's network, if any.

Answer 2b:

As of October 13, 2017, NASA has identified no active instances of Kaspersky Lab subcomponents in third party hardware or software on the Agency's network.

Kaspersky Lab software is not part of the Agency's enterprise-licensed, core-load anti-virus software. Since 2010, NASA has used Symantec Endpoint Protection as its core-load anti-virus solution under our End User Service contract.

Question 2c:

Have any of your agency's contractors or subcontractors indicated that they have searched for Kaspersky Lab subcomponents in third party hardware or software on computer products that are connected to your agency's networks?

Answer 2c:

NASA Security Operations Center (SOC) actively monitors the network for any potential Kaspersky Lab related communications and Agency contractors perform regular enterprise network and local scans to identify vulnerabilities as part of NASA's Continuous Monitoring Program. These scans include searching for Kaspersky Lab subcomponents in third party hardware and software connected to the Agency's networks.

Question 2d:

Have any of your agency's contractors or subcontractors indicated that they have discovered Kaspersky Lab subcomponents in third party hardware or software on computer products that are connected to your agency's networks? If so, please indicate how many Kaspersky Lab subcomponents they have identified and if they have all been removed.

Answer 2d:

NASA's process for discovering Kaspersky Lab subcomponents involves enterprise and local level scans for any connections to the NASA network, in combination with manual inquiries at the system owner level. All subcomponents in third party software or hardware connected to the Agency's networks have been identified and mitigated, as reported in BOD 17-01. As of Dec. 6, 2017, NASA OCIO is unaware of any indication from a contractor or subcontractor that they have discovered Kaspersky Lab subcomponents in third party hardware or software on computer products.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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November 29, 2017

Ms. Renee P. Wynn
Chief Information Officer
National Aeronautics and Space Administration
300 E Street SW
Washington, DC 20546

Dear Ms. Wynn:

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the hearing entitled, *Bolstering the Government's Cybersecurity: A Survey of Compliance with the DHS Directive* on November 14, 2017.

You have received a verbatim electronic transcript of the hearing for your review. The Committee's rule pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee and Subcommittees shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved.*

Transcript edits, if any, should be submitted no later than December 13, 2017. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **Please respond to these questions by December 13, 2017.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Chase Kassel at chase.kassel@mail.house.gov. If you have any further questions or concerns, please do not hesitate to contact the Committee staff at 202.225.6371.

Thank you again for your testimony.

Sincerely,

Darin LaHood

Darin LaHood
Chairman
Subcommittee on Oversight

cc: Rep. Don Beyer
Ranking Member
Subcommittee on Oversight

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Bolstering the Government's Cybersecurity:
A Survey of Compliance with the DHS Directive"

Ms. Renee Wynn,
Chief Information Officer,
National Aeronautics and Space Administration

Questions Submitted by Ranking Member Donald S. Beyer, Jr.,
Subcommittee on Oversight,
House Committee on Science, Space, and Technology

QFR #1: Pre-installed Software on Agency Computers
During the hearing, in response to questions about federal government computers using Kaspersky Lab software, Ms. Manfra from the Department of Homeland Security stated that of the federal government computers found using Kaspersky Lab software, most were not specifically procured by the respective agencies, but came from bulk hardware purchases with Kaspersky Lab software pre-installed.

- QFR #1A) Does your agency ever accept pre-installed software on agency-purchased computers?

- QFR #1B) If so, please indicate the security process the agency uses to minimize the security threat these acquired computers can pose?

- QFR #1C) Does the agency have a policy of "wiping" all purchased computers before connecting them to the agency's computer network?

QFR #2: Kaspersky Lab Subcomponents on Federal Networks
According to information on its website, Kaspersky Lab offers software development kits for integration into third party hardware and software. Some Kaspersky Lab products are reportedly used within other companies' hardware products, including those of Cisco, Juniper and Microsoft—though these relationships are not always explicitly disclosed in product information.

- QFR #2A) What efforts has your agency taken to insure that Kaspersky Lab software embedded in third-party products is eliminated from federal government systems, as ordered by DHS Binding Operational Directive (BOD) 17-01, issued on September 13, 2017?

- QFR #2B) Please indicate the number of Kaspersky Lab subcomponents identified in third party hardware or software on your agency's network, if any.

- QFR #2C) Have any of your agency's contractors or subcontractors indicated that they have searched for Kaspersky Lab subcomponents in third party hardware or software on computer products that are connected to your agency's networks?

- QFR #2D) Have any of your agency's contractors or subcontractors indicated that they have discovered Kaspersky Lab subcomponents in third party hardware or software on computer products that are connected to your agency's networks? If so, please indicate how many Kaspersky Lab subcomponents they have identified and if they have all been removed.

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

March 1, 2018

Reply to Attn of: OLIA/2018-00008:SWQ:dac

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed is material requested for the record and responses to written questions submitted by Ranking Member Bera and Representative Perlmutter resulting from the December 6, 2017, hearing, ***"NASA's Next Four Large Telescopes."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: Ranking Member Ami Bera

Material requested for the record on page 43, line 907, by Chairman Babin during the December 6, 2017 hearing at which Mr. Thomas Zurbuchen testified.

Why was the decision made to launch the $8B JWST on the European Ariane 5 rocket instead of a reliable U.S. launch vehicle? Was cost the only consideration?

Answer:

During the mission concept phase in the late 1990s, European and Canadian scientists and the European Space Agency (ESA) and Canadian Space Agency (CSA) expressed interest in participating in the Webb mission (during this time it was referred to as the Next Generation Space Telescope prior to being re-named the James Webb Space Telescope). The participation was to follow along the lines of other NASA collaborations whereby international partners would contribute hardware on a no-exchange-of-funds basis for a guaranteed fraction of observing time on the facility.

As with the Hubble Space Telescope, ESA and the European science community wanted to utilize roughly 15 percent of the observing time for their science, meaning that their hardware contribution needed to be valued at roughly 15 percent of the NASA cost. To reach that level, ESA committed to provide the Near Infrared Spectrograph, half of the Mid-Infrared Instrument (MIRI), the launch vehicle, some additional hardware and operations personnel at the Space Telescope Science Institute (STScI) located in Baltimore, Maryland.

A launch vehicle contribution presents a relatively small number of simple and well-defined interfaces, and thus is an attractive option from a technical viewpoint and it also is of the right value. ESA offered to build the spacecraft bus, but the complex and large number of technical interfaces, not to mention International Trade in Arms Regulations (ITAR) restrictions, led our Standing Review Board to strenuously recommend that NASA not accept the spacecraft bus as an ESA hardware contribution. Having a significant portion of Europe's Webb contribution come in the form of a launch vehicle avoids these complications.

The Ariane 5 is a proven launcher. As of December 2017, Ariane 5 performed its 82nd consecutive successful mission since 2003. Its most recent launch, on January 25, 2018, had an anomaly during ascent. Initial investigations from Arianespace reveal a trajectory deviation following launch. NASA is confident the direct cause of the anomaly will be identified and corrected for the vehicle to launch Webb successfully. ESA invited NASA participation in its review of the January Ariane launch deviation so that the agency has additional, direct insight to the event. Independent of the most recent launch, both ESA and NASA had instituted additional reviews and insight opportunities into preparations for the launch to ensure success because of the considerable cost and complexity of Webb. This increased insight and collaboration has enabled Webb to tailor its hardware and testing program specifically for launch on the Ariane 5. Our as-built and tested structures are precisely tuned to the vibration and acoustic environments of the Ariane 5.

Material requested for the record on page 43, line 913, by Chairman Babin during the December 6, 2017 hearing at which Mr. Thomas Zurbuchen testified.

What are the risks associated with the transporting of JWST to the European launch site located in South American French Guiana?

Answer:

The primary risk associated with shipping the telescope is the weather and sea conditions along the route. NASA has, and will continue to work with the USTRANSCOMM (DoD) to assess threats both natural (seas, weather) and otherwise leading up to and during the shipping. ESA uses this very same ship to send components to Kourou, so it has a well-established process. NASA has already sent instruments on two separate ship voyages to gather data on the accelerations and environments that the shipping container will experience in route. All measurements indicate that the shipping container provides adequate protection against contamination and that accelerations are within safe limits.

Material requested for the record on page 52, line 1134, by Representative Brooks during the December 6, 2017 hearing at which Mr. Thomas Zurbuchen testified.

When will the agency announce a specific launch readiness date within this window and how will it determine that this new launch readiness date is realistic?

Answer:

NASA will conduct a schedule review in the coming weeks. The results of the schedule review, along with outcomes from this spring's environmental testing of the spacecraft element, will inform the selection of a launch readiness date. The Webb launch readiness date will be announced after those activities are complete.

Material requested for the record on page 61, line 1363, by Representative Dunn during the December 6, 2017 hearing at which Mr. Thomas Zurbuchen testified.

Why are we launching the James Webb on the Ariane? Is it just cost? Why are we using a European missile rather than a good, old-fashioned American rocket?

Answer:

During the mission concept phase in the late 1990s, European and Canadian scientists and the European Space Agency (ESA) and Canadian Space Agency (CSA) expressed interest in participating in the Webb mission (during this time it was referred to as the Next Generation Space Telescope prior to being re-named the James Webb Space Telescope). The participation was to follow along the lines of other NASA collaborations whereby international partners would contribute hardware on a no-exchange-of-funds basis for a guaranteed fraction of observing time on the facility.

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HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA's Next Four Large Telescopes"

Dr. Thomas Zurbuchen, Associate Administrator, Science Mission Directorate, NASA

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

Question 1:

NASA has funded four large mission concept studies in preparation for the National Academies 2020 astronomy and astrophysics decadal survey. What considerations went into NASA's decision to provide the decadal committee with these studies? Please provide an overview of each of the four candidate mission concepts. How will NASA ensure a level playing field among all four concepts leading up to the decadal survey?

Answer 1:

What considerations went into NASA's decision to provide the decadal committee with these studies?

The mission concept selection and study process is described in detail in *Planning for the 2020 Decadal Survey: An Astrophysics Division White Paper* (https://science.nasa.gov/astrophysics/2020-decadal-survey-planning).

Several significant considerations contributed to the decision to provide this set of studies. All of these concepts are based on prioritization by the astrophysics community, and the decision to provide the decadal committee with these studies was endorsed by multiple advisory groups, including the (former) NASA Advisory Committee (NAC) Astrophysics Subcommittee and two committees of the National Academies: the Committee on Astronomy and Astrophysics and the Committee for a Midterm Assessment of the Decadal Survey.

The starting set of mission concepts were those identified as the community's highest priorities in two reports: the 2010 Decadal Survey and the 2014 NASA Visionary Roadmap, *Enduring Quests, Daring Visions*. The three Astrophysics Program Analysis Groups (PAG) each solicited community input on the set of mission concepts, including regarding whether concepts should be added or removed from the study set, and reported the results to the (former) NASA Advisory Committee (NAC) Astrophysics Subcommittee. The Astrophysics Subcommittee considered the PAG input and delivered a consolidated set of recommendations of concepts to study to NASA. The PAGs unanimously endorsed the four mission concepts identified in the Decadal Survey and the NASA Visionary Roadmap, and the Astrophysics Subcommittee reported out that NASA should study that set.

Please provide an overview of each of the four candidate mission concepts.

The mission concepts are, in alphabetical order:

- Habitable-Exoplanet Imaging Mission: An observatory designed to directly image planetary systems around Sun-like stars. Its main goal is to directly image Earth-like exoplanets and characterize their atmospheric content;
- Large UV/Optical/IR Surveyor: A large ultraviolet, optical, and infrared observatory with improvements in sensitivity, spectroscopy, high contrast imaging, astrometry, angular resolution and/or wavelength coverage;
- Lynx X-ray Surveyor: X-ray observatory with a large gain in collecting area, angular resolution, and spectroscopic capabilities over previous observatories; and,
- Origins Space Telescope: A far infrared observatory with improvements in sensitivity, spectroscopy, and angular resolution.

How will NASA ensure a level playing field among all four concepts leading up to the decadal survey?

A level playing field among the concepts will be ensured by, among other means, structuring all of the study teams in the same manner, making the same resources available to each team, subjecting each to the same milestones and deadlines, and ensuring communication between teams. Each team presented its progress to the community at the January 2018 meeting of the American Astronomical Society. Each team will provide an interim report to NASA by March 2018 that will be reviewed to assess progress and provide feedback to each team. Finally, each team will provide a final report to NASA in 2019 that will be submitted to the Decadal Survey Committee. The Astrophysics Division also routinely monitors the progress of each team and provides feedback as necessary to ensure that they will provide suitable input to the Decadal Survey Committee.

Question 2:

The development of the Transiting Exoplanet Survey Satellite (TESS) mission is proceeding with an anticipated March 2018 launch date, despite the project's detection of an unexpected drift in focus that will reduce the sensitivity in the telescope's cameras. To determine if the focus drift is stable over long periods of exposure to low temperatures, NASA continues to test a flight spare camera. What will NASA do a further drift in the focus is found after TESS is launched?

Answer 2:

It is technically incorrect to state that the TESS cameras are "out of focus." TESS is a photometry mission--not an imaging mission--and therefore there is not a single focus value over the field of view. The unexpected shift in focus, noted in the above question, refers to a shift in the location on the focal plane that is in best focus. Since TESS is a wide field photometry (not imaging) mission, the TESS cameras were never designed to have a sharp focus across the field-of-view. Test data collected on all four flight cameras indicates an optimal focus over as wide a solid angle as was specified in the mission requirements, even with the observed shift in focus. More than one year of ground test data from all four TESS flight cameras indicates that the mission will meet the TESS Level 1 Science Requirements.

The change in focus that was observed in early ground-based testing of the TESS cameras is best described as a "shift in focus" rather than a "drift in focus." After a relatively short time (~1 week) at the selected flight operating temperature, the focus stabilizes and stops drifting. This behavior has been fully verified in months of ground testing of a flight spare camera that is identical to the four flight cameras. If an additional shift should occur for any of the TESS cameras in flight, NASA will follow its standard procedures for assessing both cause and impact, and for determining what actions, if any, are needed to ensure meeting the TESS mission success criteria. One such action could be to incorporate into the TESS data processing pipeline advanced ground-based photometry software—developed since the initiation of the TESS mission—which can track slowly changing image shapes, thus further improving the signal-to-noise ratio for the TESS photometric signals.

The fact that extended flight spare camera testing has revealed no additional long-term focus shift provides high confidence that no additional drift will be observed on orbit. Furthermore, the flight spare camera will continue to be available on the ground to support assessment of any anomalous behavior exhibited by the flight cameras in orbit.

Question 3:

Your testimony indicated that the recently announced 5-8 month delay to the James Webb Space Telescope (JWST) October 2018 launch date will not result in the project exceeding the congressionally mandated $8B cost cap. Are program level reserves being used to ensure that JWST stays within the cost cap? What level of cost reserves remains at the project and program levels to accommodate any unforeseen issues that may arise in the upcoming integration and testing efforts? In view of the delayed launch, do you envision the contractor receiving any award fee penalty for this current period of performance?

Answer 3:

The James Webb Space Telescope program has sufficient reserve funding (a combination of both Goddard Space Flight Center project-held reserves and Headquarters program-held reserves) to cover the launch date change from October 2018 to a March through June 2019 window. Currently, accounting for all encumbrances, liens and threats tracked in the project risk system, the program has 42 percent contingency on the remaining work. The Webb reserve phasing was purposely back loaded to account for our uniquely difficult integration and test program. The Webb contract fee structure has components for business management, cost, schedule, and technical performance. NASA uses award fee and other tools to manage contractors supporting our missions. During the period covering the launch date change (April 1, 2017 to September 30, 2017) the contractor received no fee for their schedule performance component. Some fee was awarded for solid performance in the technical (i.e., flight hardware) and business management (communication, small business contracting, financial reporting) areas. Some fee was awarded in the cost component area as the contractor did take steps to reduce cost in areas not affected by the delay in schedule.

Question 4:

The availability of a 2.4-meter telescope for use on the Wide-Field Infrared Survey Telescope (WFIRST) opened up the possibility of incorporating a coronagraph into the mission design. Can you describe NASA's process for coming to the decision to include the coronagraph on WFIRST? When did the coronagraph officially become a part of the mission architecture? What opportunity, if any, did members of the astronomy and astrophysics community have to provide input into that decision?

Answer 4:

Can you describe NASA's process for coming to the decision to include the coronagraph on WFIRST?

The 2010 Decadal Survey in Astronomy and Astrophysics (*New Worlds, New Horizons in Astronomy and Astrophysics*, National Academies, 2010) recommended that NASA pursue a "new worlds technology development program... to lay the technical and scientific foundations for a future space imaging and spectroscopy mission." When the 2.4 m telescope was made available to NASA, the Agency recognized that one possible way of fulfilling this recommendation would be to add a coronagraph to WFIRST. Accordingly, when NASA chartered a community-based science definition team in 2012 to develop a concept for a 2.4 m version of WFIRST, this team considered the potential benefits of a coronagraph. The team provided a report on in April 2013 that concluded that the coronagraph would be "an exciting extension in [WFIRST's] capability that would not only characterize giant planets around the nearest stars, but also be an important step towards detecting habitable exoEarths." NASA then commissioned the National Academies to assess this mission concept, documented in a March 2014 report entitled *Evaluation of the Implementation of WFIRST/AFTA in the Context of New Worlds, New Horizons in Astronomy and Astrophysics* (National Academies, 2014). This panel found that the coronagraph "satisfies some aspects of the broader exoplanet technology program" recommended by the *New Worlds, New Horizons* report, but noted the risk of including the lower-maturity instrument and therefore recommended that NASA "move aggressively to mature the coronagraph design and develop a credible cost, schedule, performance, and observing program." From July to December 2013, NASA's Exoplanet Exploration Program Office sponsored a working group to identify the optimal candidate coronagraph architecture to be used in future WFIRST studies. The working group, composed of all NASA-supported coronagraph technology developers, reached consensus on the specific architecture.

The 2019 Budget proposes to terminate the WFIRST mission given its significant cost and higher priorities within NASA. Some funding made available from the proposed termination is redirected towards other priorities of the astrophysics community, including competed astrophysics missions and research.

When did the coronagraph officially become a part of the mission architecture?

NASA makes no official decisions on the scope of any mission until the project passes Key Decision Point A (KDP-A) and receives approval to formally enter Phase A and begin mission formulation. In conjunction with KDP-A, NASA issues a formulation authorization document (FAD) to define the mission scope. Therefore, the coronagraph officially became a part of the mission architecture when WFIRST passed KDP-A in February 2016. The Science Mission Directorate directed that the coronagraph instrument be included in the mission design as a technology demonstration.

The 2019 Budget proposes to terminate the WFIRST mission given its significant cost and higher priorities within NASA and provides no funding for the mission, including the coronagraph.

What opportunity, if any, did members of the astronomy and astrophysics community have to provide input into that decision?

As stated above, the Decadal Survey provided the initial prioritized recommendation for coronagraph technology development. A community-based, competitively-selected science definition team developed a concept for the WFIRST mission with the coronagraph, initially as an option. An independent National Academies review assessed the value of the coronagraph and found it to be responsive to the Decadal Survey. A team of technologists, including non-NASA participants, recommended the specific architecture of the coronagraph to be included on WFIRST. The WFIRST mission concept was presented multiple times to community-based advisory committees, including the NASA Advisory Council Astrophysics Subcommittee, the NASA Advisory Council Science Committee, the National Academies' Committee on Astronomy and Astrophysics, and the National Academies' Space Studies Board. In addition, the National Academies' Midterm Assessment of progress on the Decadal Survey (*New Worlds, New Horizons: A Midterm Assessment*, National Academies, 2016) stated that the coronagraph makes WFIRST an "ambitious and powerful facility that will significantly advance the scientific program envisioned by [*the Decadal Survey*]."

Question 5:

In your October 2017 memo to the Goddard Space Flight Center directing a design modification study for WFIRST, you directed that the coronagraph be treated as a technology demonstration instrument. Can you explain the costs associated with the coronagraph's treatment as a technology demonstration versus a science instrument? What impact would such a designation have on the management of the program? Has NASA ever included a technology demonstration on a high priority mission like WFIRST in the past?

Answer 5:

Can you explain the costs associated with the coronagraph's treatment as a technology demonstration versus a science instrument?

By replacing the coronagraph science requirements with less-ambitious technology requirements, NASA is reducing the risk that the cost of the coronagraph will increase during development. As a technology demonstration instrument, the coronagraph will have a simpler design, with fewer operating modes; this will make the instrument easier to build and test without significantly affecting its value as a technology pathfinder. In addition, treating the coronagraph as a technology demonstration instrument allows NASA to (1) eliminate the coronagraph science team; (2) reduce the coronagraph data processing requirements; and (3) eliminate the coronagraph "general observer" program.

What impact would such a designation have on the management of the program?

The management of the coronagraph instrument has not changed. However, the 2019 Budget proposes to terminate the WFIRST mission given its significant cost and higher priorities within NASA.

Has NASA ever included a technology demonstration on a high priority mission like WFIRST in the past?

NASA has had technology demonstrations connected with science missions (including missions that have science-related objectives), in some cases with significant visibility. Examples of past and potential future technology demonstrations include the following:

- A synthetic aperture radar mapping instrument on Lunar Reconnaissance Orbiter (LRO), which is a ~$500M-class mission launched in 2009 and described as being "essential for planning NASA's future human and robotic missions to the Moon";
- An optical communications demonstration on the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission, a ~$200M-class mission launched in 2013; and,
- NASA is including an oxygen-production demonstration (Mars Oxygen In-Situ Resource Utilization Experiment or MOXIE). Mars 2020 is a large mission with an estimated cost of approximately $2B.

Question 6:

In your October 2017 memo to the Goddard Space Flight Center directing a design modification study for WFIRST, you directed reductions to the coronagraph, the widefield instrument, and the cost of science investigations. Will these reductions result in a reduction in WFIRST's science return? If so, how much? How will NASA ensure that the final design of WFIRST is optimized to meet the science goals set forth in the 2010 astronomy and astrophysics decadal survey, which recommended WFIRST as the highest priority large space mission for the 2010-2020 decade?

Answer 6:

Will these reductions result in a reduction in WFIRST's science return? If so, how much?

The directed reductions to WFIRST were taken with the intent to preserve science capability to the extent possible, while still meeting the cost reduction target.

While the Goddard Space Flight Center is studying modifications to the current WFIRST design, the performance of the Wide Field Instrument is unaltered. However, NASA is reducing science center services for the Wide Field Instrument. Although the scientific potential of the Wide Field Instrument is unaffected, individual scientists may have to do a bit more work to complete their analysis of the data they receive. The net effect on science productivity should be minimal. The performance of the coronagraph in each mode is not reduced, although the number of modes is reduced, thereby affecting the potential science return. In addition, the changes described in Answer 5 above will make the coronagraph less easily usable for science investigations. Scientists will have to work very closely with the coronagraph instrument team to use coronagraph flight data for science investigations. As a result, there may be a reduction in science investigations. However, NASA's ability to fulfill the WFIRST coronagraph's main purpose, i.e., laying the groundwork for future direct imaging missions, will not be affected.

The 2019 Budget proposes to terminate the WFIRST mission and redirects some existing funding to competed research, including principal-investigator-led astrophysics missions that have a history of providing high science return while training the next generation of scientists and engineers.

How will NASA ensure that the final design of WFIRST is optimized to meet the science goals set forth in the 2010 astronomy and astrophysics decadal survey, which recommended WFIRST as the highest priority large space mission for the 2010-2020 decade?

The changes above are designed specifically to preserve WFIRST's ability to meet or exceed Decadal Survey science objectives while also meeting Midterm Assessment expectations of cost control to preserve a balanced astrophysics program. The mission science requirements were drafted and/or reviewed by the WFIRST Formulation Science Working Group (FSWG). FSWG members are selected from the community, and are tasked with ensuring that WFIRST will meet or exceed Decadal Survey goals.

The Budget proposes to terminate WFIRST and increase funding for research and principal-investigator-led missions that are high priorities in the Decadal Survey, maintaining balance within a reduced Astrophysics division budget.

Question 7:

In your October 2017 memo to the Goddard Space Flight Center directing a design modification study for WFIRST, you indicate that if the Goddard team concludes that WFIRST cannot be developed using the current 2.4-meter architecture within a $3.2B budget, you will direct a study of a WFIRST mission design consistent with the 2010 decadal survey. Does that mean that NASA remains open to the possibility of using a 1.5-meter telescope on WFIRST? Would the coronagraph technology demonstration be possible with a 1.5-meter telescope? How would the cost and risk of developing a 1.5-meter telescope from scratch compare with moving forward with the donated 2.4-meter telescope?

Answer 7:

Does that mean that NASA remains open to the possibility of using a 1.5-meter telescope on WFIRST?

We are not actively studying a 1.5-meter architecture. As previously stated, the Budget proposes to terminate WFIRST. Some funding made available from the proposed termination is redirected to competed research and missions that are high priorities in the Decadal Survey.

Would the coronagraph technology demonstration be possible with a 1.5-meter telescope?

A 1.5-meter architecture with an unobscured aperture could include a coronagraph technology demonstration, as demonstrated by the 'Exo-C' concept study for a standalone coronagraph mission (https://exoplanets.nasa.gov/exep/studies/probe-scale-stdt/). The smaller 1.5-meter aperture would significantly reduce the coronagraph's potential for scientifically meaningful observations.

How would the cost and risk of developing a 1.5-meter telescope from scratch compare with moving forward with the donated 2.4-meter telescope?

We have not done any design studies for a 1.5-meter WFIRST observatory with a coronagraph, and thus we cannot evaluate the benefits against the risk and cost. A new architecture, built around a new 1.5-meter telescope, would entail different risks than those with a 2.4-meter telescope; the relative magnitude of those risks has not been quantified.

Question 8:

The WFIRST Independent External Technical/Management/Cost Review (WIETR) report finds that a Class B risk classification for WFIRST is inconsistent with agency policy for a mission as complex as WFIRST. Does NASA plan to upgrade WFIRST to a Class A risk classification? If not, why not? If so, would there be cost impact and, if so, what would the cost impact be? If not, why not?

Answer 8:

As previously stated, the Budget proposes to terminate WFIRST. Some funding made available from the proposed termination is redirected to competed research and missions that are high priorities in the Decadal Survey.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA's Next Four Large Telescopes"

Dr. Thomas Zurbuchen, Associate Administrator, Science Mission Directorate, NASA

Questions submitted by Representative Ed Perlmutter,

House Committee on Science, Space, and Technology

Question 1:

As discussed during the hearing, the University of Colorado Boulder was instrumental in developing and even holding the patent on the Starshade technology. Private partners like Northrup Grumman and Ball Aerospace have made critical investments in this technology in the past as well. Yet it seems NASA is deviating from past patterns of technology development by concentrating all of its Starshade resources within its own NASA centers instead of including universities and private partners. Can you elaborate on NASA's relationship with universities, like CU Boulder, and private partners in advancing both the development and operation of the Starshade technology going forward?

Answer 1:

NASA provides opportunities for universities and other private-sector partners to advance exoplanet-related technologies through the Technology Development for Exoplanet Missions (TDEM) component of NASA's solicitation on Strategic Astrophysics Technology (SAT). Since 2009, TDEM proposals from private institutions for starshade technology development have been selected from Northrop Grumman Aerospace Systems, Princeton University, and the University of Colorado Boulder (see https://exoplanets.nasa.gov/exep/technology/TDEM-awards/).

After five years of starshade technology development, the state-of-the-art had reached a point where individual technologies had been developed through TDEM, and the next step in starshade technology maturation needed to take place at the system level. To that end, NASA established a starshade technology development project at Jet Propulsion Laboratoty (JPL) and incorporated the teams and efforts that were ongoing through TDEM. Work on starshade technology maturation within the system construct has been subcontracted out to partners in both academia and industry. The JPL starshade technology development project continues to solicit and incorporate work performed at partner organizations, and it relies on input and review by a community based assessment committee.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6371
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January 2, 2018

Dr. Thomas Zurbuchen
Associate Administrator
Science Mission Directorate
National Aeronautics and
  Space Administration (NASA)
300 E Street SW
Washington, D.C. 20546

Dear Dr. Zurbuchen,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the December 6, 2017, hearing titled, "*NASA's Next Four Large Telescopes*."

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than **January 16, 2018**. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than January 16, 2018.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Brian Babin

Rep. Brian Babin
Subcommittee Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA's Next Four Large Telescopes"

Dr. Thomas Zurbuchen, Associate Administrator, Science Mission Directorate, NASA

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

1. NASA has funded four large mission concept studies in preparation for the National Academies 2020 astronomy and astrophysics decadal survey. What considerations went into NASA's decision to provide the decadal committee with these studies? Please provide an overview of each of the four candidate mission concepts. How will NASA ensure a level playing field among all four concepts leading up to the decadal survey?

2. The development of the Transiting Exoplanet Survey Satellite (TESS) mission is proceeding with an anticipated March 2018 launch date, despite the project's detection of an unexpected drift in focus that will reduce the sensitivity in the telescope's cameras. To determine if the focus drift is stable over long periods of exposure to low temperatures, NASA continues to test a flight spare camera. What will NASA do a further drift in the focus is found after TESS is launched?

3. Your testimony indicated that the recently announced 5-8 month delay to the James Webb Space Telescope (JWST) October 2018 launch date will not result in the project exceeding the congressionally mandated $8 billion cost cap. Are program level reserves being used to ensure that JWST stays within the cost cap? What level of cost reserves remains at the project and program levels to accommodate any unforeseen issues that may arise in the upcoming integration and testing efforts? In view of the delayed launch, do you envision the contractor receiving any award fee penalty for this current period of performance?

4. The availability of a 2.4-meter telescope for use on the Wide-Field Infrared Survey Telescope (WFIRST) opened up the possibility of incorporating a coronagraph into the mission design. Can you describe NASA's process for coming to the decision to include the coronagraph on WFIRST? When did the coronagraph officially become a part of the mission architecture? What opportunity, if any, did members of the astronomy and astrophysics community have to provide input into that decision?

5. In your October 2017 memo to the Goddard Space Flight Center directing a design modification study for WFIRST, you directed that the coronagraph be treated as a technology demonstration instrument. Can you explain the costs associated with the coronagraph's treatment as a technology demonstration versus a science instrument? What impact would such a designation have on the management of the program? Has

NASA ever included a technology demonstration on a high priority mission like WFIRST in the past?

6. In your October 2017 memo to the Goddard Space Flight Center directing a design modification study for WFIRST, you directed reductions to the coronagraph, the widefield instrument, and the cost of science investigations. Will these reductions result in a reduction in WFIRST's science return? If so, how much? How will NASA ensure that the final design of WFIRST is optimized to meet the science goals set forth in the 2010 astronomy and astrophysics decadal survey, which recommended WFIRST as the highest priority large space mission for the 2010-2020 decade?

7. In your October 2017 memo to the Goddard Space Flight Center directing a design modification study for WFIRST, you indicate that if the Goddard team concludes that WFIRST cannot be developed using the current 2.4-meter architecture within a $3.2 billion budget, you will direct a study of a WFIRST mission design consistent with the 2010 decadal survey. Does that mean that NASA remains open to the possibility of using a 1.5-meter telescope on WFIRST? Would the coronagraph technology demonstration be possible with a 1.5-meter telescope? How would the cost and risk of developing a 1.5-meter telescope from scratch compare with moving forward with the donated 2.4-meter telescope?

8. The WFIRST Independent External Technical/Management/Cost Review (WIETR) report finds that a Class B risk classification for WFIRST is inconsistent with agency policy for a mission as complex as WFIRST. Does NASA plan to upgrade WFIRST to a Class A risk classification? If not, why not? If so, would there be cost impact and, if so, what would the cost impact be? If not, why not?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA's Next Four Large Telescopes"

Dr. Thomas Zurbuchen, Associate Administrator, Science Mission Directorate, NASA

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

1. As discussed during the hearing, the University of Colorado Boulder was instrumental in developing and even holding the patent on the Starshade technology. Private partners like Northrup Grumman and Ball Aerospace have made critical investments in this technology in the past as well. Yet it seems NASA is deviating from past patterns of technology development by concentrating all of its Starshade resources within its own NASA centers instead of including universities and private partners. Can you elaborate on NASA's relationship with universities, like CU Boulder, and private partners in advancing both the development and operation of the Starshade technology going forward?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

February 26, 2018

Reply to Attn of: OLIA/2018-00051:SWQ

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Ranking Members Bera and Johnson resulting from the January 17, 2018, hearing, ***"An Update on NASA Commercial Crew Systems Development."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: The Honorable Ami Bera, Ranking Member

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Commercial Crew Systems Development"

Mr. William Gerstenmaier, Associate Administrator, HEOMD, National Aeronautics and Space Administration

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

Question 1:

During your oral testimony, you stated, "We are brainstorming ideas to provide additional schedule time, if needed. Additionally, as we do this, we are looking for ways to allow the partners to reach an operational tempo after certification." Please provide details on the options being considered to provide additional schedule time and ways to allow the partners to reach an operational tempo.

Answer 1:

NASA is considering extending the length of the crewed test flights which could provide some additional flexibility for mission planning. Other options are not mature at this time.

Question 1a:

How will those options be evaluated?

Answer 1a:

The primary considerations will be the ability of the option to mitigate schedule issues, cost and risk.

Question 2:

During the Space Shuttle Program, NASA investigated increasing lift performance by using densified propellants. Please explain why NASA considered the use of densified propellants on the Space Shuttle and why NASA decided against its use. What were the concerns relative to safety? What other concerns led to the decision not to use densified propellants on the Space Shuttle?

Answer 2:

NASA did investigate the use of densified (i.e. superchilled) propellants as early as the 1970s, and revisited the idea in the 1990s as a potential way to increase the performance of the Space Shuttle. Ultimately, the decision to pursue other opportunities was based, not on safety, but on the technical difficulty (and likely associated cost and schedule impacts) of certifying components and systems able to handle densified propellants into the existing Shuttle system.

On the vehicle side, the multitude of pumps, complex propellant lines, and main engines on the Orbiter were all originally designed and built for "normal" cryogenic propellant temperatures; the challenges of re-testing and recertifying this entire system at densified propellant temperatures would have been substantial and disruptive to Shuttle flight operations.

Operationally, the Shuttle ground systems at the Kennedy Space Center would have also required significant modifications to facilities and procedures to tank and maintain densified propellant temperatures.

In the end, other technical solutions (such as the introduction of the Super Lightweight External Tank and increased Space Shuttle Main Engine performance) obviated the need for densified propellants, and increased Shuttle performance to the point which would enable Shuttle to deliver and assemble the large elements in the high inclination orbit of the International Space Station.

Question 3a:

During the question and answer session of the hearing, you stated that "we will find the appropriate time, along with the contractors, to put crew on this particular vehicle design that is most appropriate for the lowest risk to the crews."

Do I understand correctly that NASA's sole question regarding SpaceX's use of densified propellant is "when" crew would be put on board the Crew Dragon and not "if" NASA will accept the risks associated with loading propellants while crew are onboard?

Answer 3a:

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.

Question 3b:

Is NASA working with <u>both</u> providers to determine the appropriate time to put crew on the vehicles, as you indicated during the hearing discussion? If so, is there a question as to when crew would board the Starliner crew vehicle, which would launch on the Atlas 5 launch vehicle?

Answer 3b:

Crew ingress timelines for Boeing's crew transportation system have already been baselined. Crew ingress will occur after propellant has been loaded on the launch vehicle.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Commercial Crew Systems Development"

Mr. William Gerstenmaier, Associate Administrator, HEOMD, National Aeronautics and Space Administration

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

Question 1a:

According to a NASA document, gaps in the U.S. crewed presence on the ISS "at any point would diminish vehicle operations to an inoperable state." If that is the case,

When is the last Soyuz flight with a NASA crew seat paid for by NASA scheduled?

Answer 1a:

The last scheduled Soyuz flight with a NASA crew seat paid for by NASA is currently scheduled to launch in May 2019 and return in November 2019.

Question 1b:

By when would a post-certification commercial crew transfer mission need to occur to prevent any gaps in U.S. crewed presence?

Answer 1b:

At this point, given current schedules and plans, the first post certification commercial crew mission would need to occur in the fall 2019.

Question 1c:

What is NASA's contingency plan if the commercial crew providers are not ready to be operational by the time we use the last Soyuz seat purchased from Boeing?

Answer 1c:

NASA is in the process of developing options to provide additional schedule time. NASA is considering extending the length of stay aboard the ISS for the crewed test flights, which could provide some additional flexibility for mission planning. Other options are not mature at this time.

Question 2a:

Both Boeing and SpaceX are currently planning for a crewed flight test in 4th quarter 2018 and certification review in 1st quarter 2019. That schedule would allow just a matter of a few months between the crewed test flight and final certification.

What activities need to be completed by NASA and the contractors between the crewed flight test, and the certification review?

Answer 2a:

All data from the crewed test flight will need to be reviewed and evaluated. If there are any anomalies during the flight, they will have to be evaluated and addressed. An Operations Readiness Review milestone must be successfully completed post-crewed test flight prior to certification for both companies. Also, a final human rating certification package will need to be approved by NASA.

Question 2b:

Are both providers allowing adequate time in their schedules to complete these activities? If yes, what is the basis for that determination?

Answer 2b:

The partner schedules are aggressive, but achievable. NASA independently reviews and evaluates the partner schedules on a monthly basis. NASA will make sure that the proper time is allocated for these activities.

Question 3a:

Will all Commercial Crew Program crew be fully trained on both the Starliner and the Crew Dragon?

Answer 3a:

For crewed test flights, NASA will make specific crew assignments from the current crew cadre. Crewmembers are trained specifically for the test flight on that particular vehicle.

For operational flights, ISS crew are trained in detail for the vehicle they are assigned to. However, all crewmembers will have basic familiarization and emergency training for all vehicles docked at ISS.

Question 3b:

How will NASA handle crew assignments if one vehicle is not flight ready or experiences a significant delay?

Answer 3b:

NASA does not anticipate that schedule delays will affect the crew assignments.

Question 4:

During the hearing, you indicated that NASA would continue to fly astronauts on Soyuz spacecraft and mentioned that, in turn, NASA would provide a seat to a Russian crewmember on U.S. commercial crew vehicles once they are operational. You noted that the exchange of seats is for safety considerations and to ensure that a mixed U.S. and Russian crew is maintained on the ISS. When do you anticipate that a seat on the Soyuz, under a no-exchange-of-funds arrangement, will first be used?

Answer 4:

According to current flight planning, we anticipate a U.S. crewmember flying on a Soyuz under this new model to launch in September 2019.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

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February 2, 2018

Mr. William Gerstenmaier
Associate Administrator, HEOMD
National Aeronautics and
Space Administration
300 E Street SW
Washington, D.C. 20546

Dear Mr. Gerstenmaier,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the January 17, 2018, hearing titled, "*An Update on NASA Commercial Crew Systems Development.*"

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than February 16, 2018. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than February 16, 2018.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Brian Babin

Rep. Brian Babin
Subcommittee Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Commercial Crew Systems Development"

Mr. William Gerstenmaier, Associate Administrator, HEOMD, National Aeronautics and Space Administration

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

1. During your oral testimony, you stated, "We are brainstorming ideas to provide additional schedule time, if needed. Additionally, as we do this, we are looking for ways to allow the partners to reach an operational tempo after certification." Please provide details on the options being considered to provide additional schedule time and ways to allow the partners to reach an operational tempo.

    a. How will those options be evaluated?

2. During the Space Shuttle Program, NASA investigated increasing lift performance by using densified propellants. Please explain why NASA considered the use of densified propellants on the Space Shuttle and why NASA decided against its use. What were the concerns relative to safety? What other concerns led to the decision not to use densified propellants on the Space Shuttle?

3. During the question and answer session of the hearing, you stated that "we will find the appropriate time, along with the contractors, to put crew on this particular vehicle design that is most appropriate for the lowest risk to the crews."

    a. Do I understand correctly that NASA's sole question regarding SpaceX's use of densified propellant is "when" crew would be put on board the Crew Dragon and not "if" NASA will accept the risks associated with loading propellants while crew are onboard?

    b. Is NASA working with both providers to determine the appropriate time to put crew on the vehicles, as you indicated during the hearing discussion? If so, is there a question as to when crew would board the Starliner crew vehicle, which would launch on the Atlas 5 launch vehicle?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on NASA Commercial Crew Systems Development"

Mr. William Gerstenmaier, Associate Administrator, HEOMD, National Aeronautics and Space Administration

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

1. According to a NASA document, gaps in the U.S. crewed presence on the ISS "at any point would diminish vehicle operations to an inoperable state." If that is the case,
    a. When is the last Soyuz flight with a NASA crew seat paid for by NASA scheduled?
    b. By when would a post-certification commercial crew transfer mission need to occur to prevent any gaps in U.S. crewed presence?
    c. What is NASA's contingency plan if the commercial crew providers are not ready to be operational by the time we use the last Soyuz seat purchased from Boeing?
2. Both Boeing and SpaceX are currently planning for a crewed flight test in 4th quarter 2018 and certification review in 1st quarter 2019. That schedule would allow just a matter of a few months between the crewed test flight and final certification.
    a. What activities need to be completed by NASA and the contractors between the crewed flight test, and the certification review?
    b. Are both providers allowing adequate time in their schedules to complete these activities? If yes, what is the basis for that determination?
3. Will all Commercial Crew Program crew be fully trained on both the Starliner and the Crew Dragon? How will NASA handle crew assignments if one vehicle is not flight ready or experiences a significant delay?
4. During the hearing, you indicated that NASA would continue to fly astronauts on Soyuz spacecraft and mentioned that, in turn, NASA would provide a seat to a Russian crewmember on U.S. commercial crew vehicles once they are operational. You noted that the exchange of seats is for safety considerations and to ensure that a mixed U.S. and Russian crew is maintained on the ISS. When do you anticipate that a seat on the Soyuz, under a no-exchange-of-funds arrangement, will first be used?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

June 20. 2018

Reply to Attn of: OLIA/2018-00146:SWQ

The Honorable Brian Babin
Chairman
Subcommittee on Space Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Babin:

Enclosed are responses to written questions submitted by Ranking Members Bera and Johnson and Representatives Brooks and Perlmutter resulting from the March 7, 2018 hearing titled, ***"An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2019."***

The responses to material requested for the record remain outstanding at this time. This material will be forwarded to you as soon as possible.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: The Honorable Ami Bera, Ranking Member

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

QUESTION 1a:

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.

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 1a:

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.

QUESTION 1b:

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 1b:

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.

QUESTION 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 DSCVR 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 2:

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.

QUESTION 2a:

Was the science community consulted?

ANSWER 2a:

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.

QUESTION 2b:

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 2b:

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.

QUESTION 3a:

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 $8B would be at risk of being breached.

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 3a:

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.

QUESTION 3b:

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 3b:

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.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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March 22, 2018

Mr. Robert M. Lightfoot, Jr.
Acting Administrator
National Aeronautics and
Space Administration (NASA)
300 E Street SW
Washington, DC 20546

Dear Mr. Lightfoot,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the March 7, 2018 hearing titled, *"An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2019."*

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than April 5, 2018. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than April 5, 2018.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Rep. Brian Babin
Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

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?

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?

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

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

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?

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?

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.

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?

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?

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?

    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?

    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?

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?

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?

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.

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.

    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.

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 DSCVR 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?

    a. Was the science community consulted?

    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?

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?

    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?

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)

<u>Question submitted by Representative Mo Brooks, House Committee on Science, Space, and Technology</u>

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?
    b. Why was the same ORB-3 IRT report released so much faster?
    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?
    d. What steps is NASA taking so that future incident reports do not have such a delay?

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?

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?

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?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

June 11, 2018

Reply to Attn of: OLIA/2018-00229:SWQ:dac

The Honorable Andy Biggs
Chairman
Subcommittee on Environment
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Representative Perlmutter resulting from the April 26, 2018, hearing entitled, ***"Surveying the Space Weather Landscape."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: The Honorable Suzanne Bonamici, Ranking Member

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

June 11, 2018

Reply to Attn of: OLIA/2018-00229:SWQ

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Babin:

Enclosed are responses to written questions submitted by Representative Perlmutter resulting from the April 26, 2018, hearing entitled, ***"Surveying the Space Weather Landscape."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: The Honorable Ami Bera, Ranking Member

"Surveying the Space Weather Landscape"

Dr. Jim Spann, Chief Scientist, Heliophysics Division,
Science Mission Directorate, NASA

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

Question 1:

During the Subcommittee testimony numerous comments were directed at power grid vulnerabilities to space weather. What information do we have about space weather vulnerabilities of spacecraft/space hardware/space-based communication infrastructure?

Answer 1:

The space environment is an important consideration for NASA missions, as spacecraft are susceptible to the radiation in space. For example, during one space weather storm in 2003, satellite anomalies were reported by deep space missions and by satellites in all orbits. The NASA Goddard Space Flight Center Space Science Mission Operation Team indicated that approximately 59 percent of all NASA Earth and space science missions were impacted. Therefore, space weather is factored into the design, launch, and operation of spacecraft missions. For the Chandra mission, with an instrument particularly sensitive to the radiation environment near Earth, the space environment is a critical factor for day-to-day operations. A variety of automated and manual processes are used to assess space weather conditions and to alert the spacecraft and Mission Operations staff during high radiation events.

Question 2:

How do industry, civil government agencies, and the Department of Defense monitor and report problems, anomalies and vulnerabilities of their assets to space weather events?

Answer 2:

With NASA, standard anomaly investigation practices are followed. The space weather environment at the time of an anomaly is assessed as part of the anomaly investigation process. Specific monitoring and reporting vary from mission to mission. Near and long-term operational impacts are assessed, and adjustments can be made as needed to the mission planning guidelines and to on-console procedures. In addition to the resources available in the operations teams, outside technical experts can also be called upon to support anomaly investigation efforts. When adverse space weather conditions occur or are predicted, measures can be taken, such as activation of the high-radiation response protocol used by the Chandra mission.

Question 3:

How could an anonymized database for on-orbit spacecraft and communication anomalies provide important information on the routine impacts of space weather events on space-based infrastructure?

Answer 3:

Ongoing research funded by NASA will improve specification and forecast models of the environmental conditions that cause spacecraft anomalies. An improved understanding of when and where anomalies occur, as could be obtained from a database, would benefit researchers developing numerical models by indicating the conditions of highest concern.

Enhanced understanding, through these models, could improve responses to space weather, such as the shutdown of components, changes in operating modes, and the reconfiguration of fault management logic.

Question 4:

How can the government better leverage next generation observing platforms, such as cubesat constellations, and what types of important measurements can be taken, and at what locations, to best inform space weather forecasting units about the status of the space environment?

Answer 4:

There are several space platforms that can be leveraged to advance the understanding of the space environment variability that will better inform space weather forecasting entities. These platforms include the evolving small satellite capabilities, including CubeSats, and remote sensing solar observing and near-Earth space observing platforms. Constellations of small satellites, particularly in near-Earth region of space, can provide a network of many simultaneous observations of the space environment as they fly through important regions over a broad area. Remote ultraviolet observations of high latitude auroral zones and equatorial emissions could provide key insight into the dynamics of space weather. These observations of the near-earth region would improve the predictive capability of space weather in the regions of space where space weather has its greatest impact, both for spacecraft and ground systems. However, additional observations of the solar wind between the Sun and Earth, and new views of the solar surface before it rotates and faces the Earth, would also have significant impact on the current comprehension of how the observed solar eruptions occur and under what conditions they are more likely to appear.

Effectively incorporating observations into numerical prediction models is another essential aspect of informing space weather forecasts. The distributed measurements obtained from the next generation observing platforms will need to be incorporated into models to maximize specification and forecast accuracy.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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May 11, 2018

Dr. Jim Spann
Chief Scientist
Heliophysics Division
Science Mission Directorate
National Aeronautics and Space Administration
300 E Street SW
Washington, DC 20546

Dear Dr. Spann,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the April 25, 2018 joint hearing titled, "*Surveying the Space Weather Landscape*."

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than May 25, 2018. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than May 25, 2018.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Daniel Dziadon at daniel.dziadon@mail.house.gov. If you have any further questions or concerns, please contact Mr. Dziadon at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Andy Biggs

Rep. Andy Biggs
Chairman
Subcommittee on Environment

Brian Babin

Rep. Brian Babin
Chairman
Subcommittee on Space

cc: Rep. Ami Bera
Ranking Member
Subcommittee on Space

Rep. Suzanne Bonamici
Ranking Member
Subcommittee on Environment

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Surveying the Space Weather Landscape"

Dr. Jim Spann, Chief Scientist, Heliophysics Division, Science Mission Directorate, NASA

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

1. During the Subcommittee testimony numerous comments were directed at power grid vulnerabilities to space weather. What information do we have about space weather vulnerabilities of spacecraft/space hardware/space-based communication infrastructure?

2. How do industry, civil government agencies, and the Department of Defense monitor and report problems, anomalies and vulnerabilities of their assets to space weather events?

3. How could an anonymized database for on-orbit spacecraft and communication anomalies provide important information on the routine impacts of space weather events on space-based infrastructure?

4. How can the government better leverage next generation observing platforms, such as cubesat constellations, and what types of important measurements can be taken, and at what locations, to best inform space weather forecasting units about the status of the space environment?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

September 18, 2018

Reply to Attn of: OLIA/2018-00318:SWQ:dac

The Honorable Brian Babin
Chairman
Subcommittee on Space
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed is the material requested for the record and responses to written questions submitted by you and Ranking Members Bera and Johnson resulting from the June 14, 2018, hearing, ***"NASA Cost and Schedule Overruns: Acquisitions and Program Management Challenges."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: Ranking Member Ami Bera

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Stephen Jurczyk, Associate Administrator, NASA

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

Question 1

After years of reporting that conditions at NASA were improving, GAO recently found that schedule delays and cost growth are now on the upswing. Were you surprised by the upswing in schedule delays and cost growth that GAO brought to light? Are both short-term and long-term changes being considered by NASA to address the problem? If so, what are some examples?

Answer 1:

When NASA establishes a cost and schedule baseline, an associated joint cost and schedule confidence level (JCL) is provided alongside the cost and schedule figures. This confidence level is the product of a probabilistic analysis of the coupled cost and schedule to measure the likelihood of completing all remaining work at or below the budgeted levels and on or before the planned completion of the development phase. Although the JCL process quantitatively incorporates risks and threats, it does not account for two key facets that have the ability to drive cost and schedule.

- Unknown-unknowns-- although NASA's Continuous Risk Management (CRM) process aims to create as comprehensive a risk register as possible, it is not feasible to predict all events that could possibly increase cost or schedule;
- Uncertainty in the baseline estimate-- disregarding risks altogether, it is impossible to precisely predict the time or budget required to complete various segments of space vehicle research, development, and production.

As a result, there is an inherent uncertainty present in the decision to proceed with development budgeted at a 70 percent confidence level, and it must be accepted that cost and schedule overruns will occur in some projects some of the time. NASA continues to work to strengthen implementation of the JCL process and the CRM process to ensure highly informed baseline decisions. Other items underway to bolster cost and schedule improvement include:

- Looking at ways to more effectively utilize Earned Value Management (EVM) performance data in estimating the final costs of our major acquisitions;
- Evaluating procurement approaches and contract incentives;
- Communicating with our key stakeholders on inherent uncertainties and challenges, and our efforts to mitigate them; and,

- Strengthening and expanding various programmatic assessment training curricula including electronics learning, detail/transfer opportunities among Centers, and partnership with other U.S. Government organizations.

NASA utilizes Knowledge Officers, and a Chief Knowledge Officer, to ensure that all Centers operate as learning organizations. The NASA APPEL (Academy of Program/Project & Engineering Leadership) program is a resource for project management training. NASA schedules regular Virtual Project Management Challenges to train personnel and share best practices. The most recent session was held on June 21 with the topic "Big Lessons from Small(er) NASA Projects."

NASA has enhanced the Cost Analysis Data Requirement (CADRe) to more formally capture projects' risk lists for each milestone. The goal of this enhancement is to have an established dataset for analysts to utilize. For example, to better inform the programmatic and risk management communities during JCL analysis.

NASA is in the process of renewing its Corrective Action Plan associated with our high risk designation in GAO's biennial High Risk Report. As part of this plan, NASA is evaluating a range of enhancements and improvements for programmatic stewardship, including but not limited to: training curriculum implementation, contract consolidation, modernizing decision memoranda process, automating cost and schedule reporting, greater rigor on cost and schedule estimating practices, and generating clarified guidelines for forecast-driven and data-informed development phase programmatic assessment on major projects. The current target for drafting, circulating, and finalizing the new Corrective Action Plan is through the end of calendar year 2018.

Question 2:

Recent instances have occurred where avoidable mistakes were committed by contractor personnel during fabrication, assembly, testing, and integration of spacecraft. Is there an underlying cause for these unforced errors and how can they be minimized?

Answer 2:

While progress on NASA's human spaceflight programs has been substantial, NASA and its contractors have faced challenges with first-time design and assembly. Many of these challenges involved unforeseen technical issues associated with the building of cutting-edge, large, complex aerospace systems. This critical hardware has to operate in the extreme environment of space, requiring the development and implementation of state-of-the-art processes. However, other mistakes should not be expected or acceptable and have been the result of failures in execution. The learning curve has been steep, however the long-term benefits of challenging the national industrial base to produce these kinds of systems is significant. NASA's focus is on ways to further strengthen the technical rigor within Agency and prime contractors systems such that those mistakes, when they happen, are promptly detected and corrected before they substantively impact cost and/or schedule. Specific areas of recent systemic focus include:

- processes that produce predictable, repeatable results, that are not subject to interpretation, and that represent the collective learning experience of the organization, including from preventive/corrective action from past failures and anomalies;
- individuals who are properly trained in the processes, follow them in a disciplined way, and are authorized to call a halt if something in the process doesn't seem right;
- accountable individuals in functions who ensure that procedures have been properly followed prior to sign-off; and
- verification and validation testing to ensure system requirements are met.

In the case of the heavy-lift Space Launch System (SLS), NASA and core stage prime contractor Boeing are working methodically through issues that are not unexpected during the first-time production of such a large and complex piece of aerospace hardware. The team has overcome initial challenges in using advanced friction stir welding to produce the core stage liquid oxygen and liquid hydrogen tanks. Along the way, engineers working on the rocket have learned a great deal from meeting challenges (ranging from the precise alignment of weld machines to addressing the fact that tiny threads on welding pins affect weld strength) that have pushed the state-of-the-art for self-reacting friction stir welding of thicker materials. Most recently, NASA has been managing a slower than expected ramp up in outfitting the core stage, due in part to contamination recently seen in some of the propellant lines in the engine section. This contamination issue came from the subcontractor tubing supply chain. Investigation has shown this issue to be broader than SLS and involve several suppliers. It appears that the tubing suppliers do not have effective cleaning processes or processes that adequately verify cleanliness.

NASA and Boeing have implemented a number of changes that are already having a positive impact on SLS core stage production. For example, senior Boeing management is very engaged in monitoring program progress and quickly addressing challenges as soon as they occur. NASA has moved additional engineering staff to Michoud to reduce the cycle time for solving manufacturing problems in real time. Boeing has increased on-site production labor working three shifts during the week and two shifts on weekends. Boeing has also set up a dedicated core stage production operations center with integration managers coordinating daily operations, as well as a dedicated green run manager to ready the first core stage for testing at the Stennis Space Center in Mississippi starting approximately one year prior to launch.

NASA also recognizes that the lessons learned from its recent experience with the James Webb Space Telescope have similarities to other issues we are seeing around NASA's development programs, including our interaction with contractors, and it is imperative for NASA to not only internalize these messages to lasting effect on Webb, but also across all of NASA's programs. Results concerning development, management and industrial base have been discussed among Agency leaders, and NASA will be setting up an all-hands meeting with Agency development personnel so these lessons can be spread and discussed.

The successful completion of the James Webb Space Telescope is critical to advancing our understanding of the Universe. Webb will conduct world-class science, answering questions about our place in the universe – Where did we come from? Are we alone? The data acquired with Webb will underpin many future projects. The superb performance of Webb's telescope and instruments during testing have made us eager to put them to use in space toward addressing fundamental science questions. The Independent Review Board (IRB) noted that Webb has "awesome scientific potential." Despite the challenges encountered during its integration and testing, NASA is confident that Webb will achieve mission success. That confidence is increased with the implementation of the IRB's recommendations, and mission success must be NASA's driving consideration moving forward. Along with the scientific community and the public, NASA is disappointed that completing Webb is taking longer than expected, but NASA is absolutely committed to successfully completing, launching, and commissioning Webb, and to carrying out its important scientific mission.

Question 3:

How can NASA balance accountability and enforcement of contract provisions with the need to maintain a trusting, team-oriented relationship with its contractors and partners? Has the use of contract incentives such as award fees led to positive outcomes at NASA? If so, please provide some examples. What leverage does NASA have on a contractor when award fees are no longer available?

Answer 3:

NASA values the strong professional relationships that we have built with our contractors and partners over the years. It is through these strong relationships that we are able to accomplish NASA's challenging mission. It is NASA's goal to enter into contractual arrangements that contain fair and balanced terms and conditions that ensure that the contractor is incentivized to perform in an exemplary fashion in the areas of cost, schedule, and technical performance. We believe that such contractual arrangements can actually be a catalyst to building a trusting and team-oriented relationship with our contractors and partners. For example, NASA award fee procedures require interim award fee evaluations before the final award fee evaluation determination. These interim evaluations encourage continual communications between government and contractor personnel during contract performance which promotes the building of professional, team-oriented relationships. Many NASA flight programs and projects are high risk, and require special hardware or design, as well as contracting mechanisms that manage various risks. Every new concept for a space craft, a satellite, or rover comes to life through high-risk contracting. High-risk missions are always a challenge and award fee contracts, when used effectively, can assist in meeting the challenge of these high risk contracts. NASA has successfully used award fee incentives to motivate contractors to enhance contractor performance in the areas of cost, schedule, and technical performance. For example, on an award fee type contract, NASA managers made complaints regarding inconsistent support from the contractor. The award fee evaluation board for this contract was able to evaluate this performance weakness through the award fee process which incentivized the contractor to implement corrective actions. In another example, under an award fee contract, the contractor's required plan reviews were not providing the accuracy required by the government. The award fee evaluation board negatively impacted the contractor's technical score in their award fee evaluation for that period. This action got the contractor's attention and noticeable improvements were made. Beyond award fee incentives, NASA has other contractual leverage to motivate contractor performance ranging from partial payment withholdings for poor performance to recording poor contractor performance in the Contractor Performance

Assessment Reporting System (CPARs). CPARs data is utilized by Federal Agencies in competitive procurements to determine a contractor's past performance record.

Question 4:

In a 2012 report, the NASA OIG stated that funding instability can lead to inefficient management practices and encouraged NASA to both increase its efforts to determine the extent to which funding instability impacts NASA projects and to clarify the cause and effect relationship between funding instability and project increases, schedule delays, and performance problems. Has NASA implemented actions responsive to the NASA OIG's concern? What are examples of actions NASA has taken or is taking?

Answer 4:

As noted in the NASA response to the OIG findings, NASA had previously implemented many changes to mitigate the effects of funding instability. Formulation Agreements, Program Plans, Project Plans, and Decision Memoranda were implemented that document the agreements and expectations between the Agency and the program or project manager. In the Decision Memoranda, the Management Agreement (MA) defines the parameters and authorities over which the program or project manager has management control, and should be viewed as a contract between the Agency and the program or project manager. Any divergence from the MA that any party identifies, including changes in funding profiles, is to be accompanied by an amendment to the Decision Memorandum. These changes to internal practices facilitate identification of impacts, encourage discussion regarding resolution path, and document changes to the agreements. With regard to incremental funding, funds availability is continuously tracked at the project level. Any emergent issues associated with incremental funding are communicated via routine channels and quickly resolved. The specific implementation of incremental funding varies across Mission Directorates to allow for the most efficient and effective means by which to fund different types of projects balanced with fiscal control at the Mission Directorate level.

Also as noted in the NASA response to the OIG findings, external funding instability drivers are more difficult to control or influence. United States Government policies and priorities may change over time, and Continuing Resolutions may be in place for long periods of time. Instability brought on from constant Continuing Resolutions is often cited as a primary challenge in terms of project and program planning. NASA continues to seek to keep external stakeholders informed when external decisions impact a project's ability to deliver on NASA's Agency Baseline Commitment. NASA also continues to advise projects to consider the probability of a Continuing Resolution when developing and refining plans at the beginning of a fiscal year.

Question 5a-5b:

Technology changes at a rapid pace and often leads to new concepts for NASA missions and spacecraft operations. Yet, current cost models used to develop cost estimates rely heavily on historical experience.

a. To what extent are cost and schedule models keeping pace with new concepts?

b. Is NASA supporting research and development in cost and schedule modeling? If so, provide examples of existing efforts.

Answer 5a-5b:

NASA supports the research and development of cost and schedule modeling in three specific ways:

Firstly, NASA robustly collects historical cost, schedule, and technical data. Every NASA spaceflight project is required to produce a Cost Analysis Data Requirement (CADRe). Specifically, CADRe is a three-part document that describes a NASA project at each milestone, contains key technical parameters, and captures the estimated and actual cost for each element in a project. The CADRe provides historical record of cost, schedule, and technical project attributes so that estimators can better estimate future analogous projects. The first part of CADRe (Part A) describes the NASA project at each milestone and describes significant changes that have occurred since the last milestone. The second part (Part B) contains standardized templates to capture key technical parameters that are considered to drive cost and schedule (e.g., mass, power, data rates, etc.). Lastly, the third part (Part C), captures the project's cost estimate and actual life cycle costs. Each project produces a CADRe five times during its lifecycle (System Requirements Review, Preliminary Design Review, Critical Design Review, System Integration Review, Launch, and End of Mission) which creates a temporal look at how projects change, augment, or descope during their development. The primary purpose of the CADRe effort is to have the data available to improve NASA cost and schedule modeling capabilities.

Secondly, NASA devotes resources annually to improve its models. These efforts include populating existing models with new CADRe data, updating methodologies based on community best practices, and updating cost drivers based on community best practices and research. Recently launched missions are incorporated in each model as quickly as possible to support ongoing model improvements. Cost models are used not to perfectly reflect the future actual cost, but to instead provide a deeper understanding of risks and scenarios for planning and management.

Thirdly, NASA's cost and schedule community utilizes NASA CADRe to conduct research to: a) Develop new models that aim to improve estimating capability, b) Understand what drives cost and schedule performance, and/or c) Collect additional data that is not currently captured in CADRe to see if it better informs NASA cost and schedule forecasting. CADRe data capture has been improved over the years based on previously mentioned research (e.g., schedule and risk data). NASA conducts this research at various levels (e.g., project, Center, Agency). Recent Agency budget for cost and schedule research has been effectively cut.

Examples of research conducted are numerous. Some examples of research from 2013-2015 can be accessed at: https://www.nasa.gov/offices/ocfo/functions/research_analysis .

Good examples of research conducted in 2016 are:

- NICM Instrument Class: https://www.nasa.gov/sites/default/files/atoms/files/13_nicm_missionclass_2016nasacost_symposiumfinal_rev3_tagged.pdf

- CubeSat Or Microsat Probabilistic + Analogies Cost Tool: https://www.nasa.gov/sites/default/files/atoms/files/25_compact_nasa_cost_symposium_2016final2_tagged.pdf

  Good examples of research conducted in 2017 are:
  - Schedule Estimating Relationships: https://www.nasa.gov/sites/default/files/atoms/files/17_2017_nasa_symposium_ser_presentation_v5_14_august_2017_tagged.pdf
  - Cryocooler Modeling: https://www.nasa.gov/sites/default/files/atoms/files/14_nicmcryocooler_costsymposium_2017_urs_final_tagged.pdf

NASA shares community research during the annual Cost and Schedule Analysis Symposium. A more complete list of research over the years, including model improvements, can be accessed via: https://www.nasa.gov/offices/ocfo/cost_symposium .

Question 6:

GAO identified workforce challenges, including workforce skills and sufficiency of staffing, as an issue in its assessment of major projects. How does NASA factor workforce capabilities into its decisions on choosing whether to place mission development and management responsibilities at a Center or with a contractor?

Answer 6:

NASA's Office of Strategy and Plans provides leadership in the development and application of NASA's acquisition policy. This NASA Policy provides the overall policy framework for NASA's strategic acquisition process, augments the Agency governance structure for decision making, and supports obtaining or advancing the development of the systems, research, services, construction, and supplies to fulfill the Agency's mission and other activities which advance the Agency's statutory objectives. Among many considerations, this Policy requires Agency leaders to consider, when developing an acquisition strategy, the full spectrum of acquisition approaches, as appropriate, to advance the Agency's objectives, taking into consideration providing best value, maximizing competition, and preserving the Agency's core capabilities. In addition, it requires that NASA capabilities, as required by senior Agency management to efficiently and effectively implement the NASA Strategic Plan, are maintained, including workforce and infrastructure, over both the short term and long term.

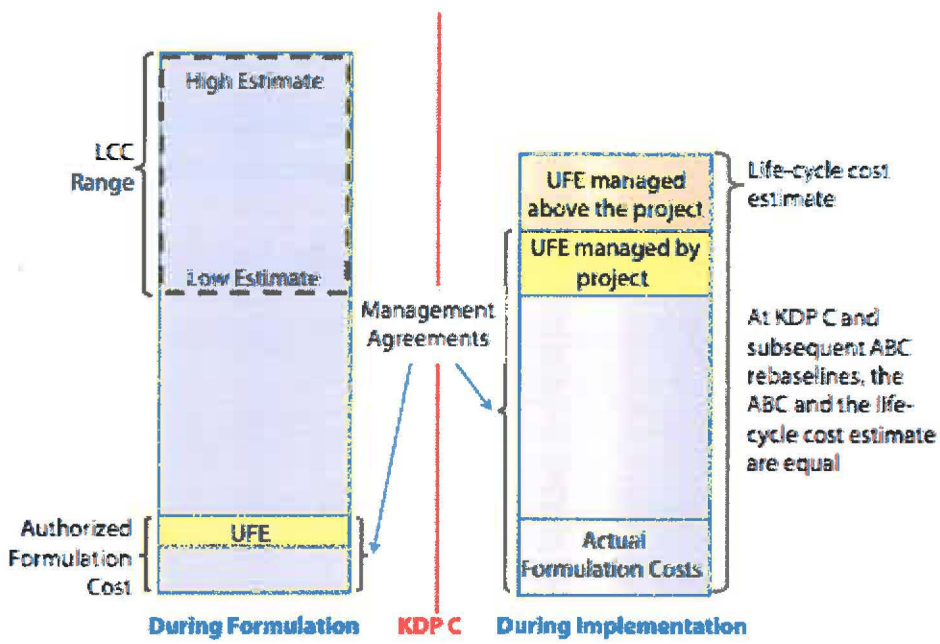
Question 7:

How does NASA determine the level of cost and schedule reserves to be included in the estimated cost of a program and how does NASA determine how much of these reserves are allocated to the project and program?

Answer 7:

For projects with a lifecycle cost greater than $250M, NASA uses probabilistic cost-loaded schedules, or Joint Cost and Schedule Confidence Level (JCL) analysis, so the program/project and the independent review entity can focus on the program/project plan. This improves program or project planning by systematically integrating cost, schedule, and risk products and processes. It also facilitates transparency with stakeholders on expectations and the probabilities of meeting those expectations. Lastly, it provides a cohesive and holistic picture of the program or project's ability to achieve cost and schedule goals and enables the determination of Unallocated Future Expenses (UFE) and funded schedule margins required by the program or project. UFE (i.e., reserves) are the portion of estimated cost required to meet the specific confidence level that cannot yet be allocated to the specific Work Breakdown Structure (WBS) sub-elements because the estimate includes probabilistic risks and specific needs that are not known until these risks are realized. For programs and projects that are not required to perform probabilistic analysis, the UFE should be informed by the program or project's unique risk posture in accordance with Mission Directorate and Center guidance and requirements. The rationale for the UFE, if not conducted via a probabilistic analysis, should be appropriately documented and be traceable, repeatable, and defendable. Otherwise, UFE is determined by the confidence level provided by the joint cost and schedule calculations. For projects with a lifecycle cost greater than $250M, the goal is to provide sufficient understanding of the risks and associated impacts on cost and schedule to allow determination of a cost estimate and its associated confidence levels with the estimate NASA commits to external stakeholders.

The Management Agreement cost figure contains sufficient UFE to meet the 50 percent confidence level as determined by the supporting probabilistic analysis. This UFE is under the control of the Project Manager. Additional UFE is held above the project level at the Program or Mission Directorate level sufficient to meet 70 percent confidence as determined by the supporting probabilistic analysis. Use of this Program or Mission Directorate UFE requires a change to the project's Management Agreement via the project's decision authority since responsibility has transferred to the project's control.



Note: Figure is notional and not drawn to scale.

Question 8:

Although NASA's collaboration with international partners has been critical to the success of many missions, some of these partnerships have encountered schedule delays. What are the lessons learned from instances of schedule delay with international partners? What, if any, steps can NASA take to mitigate the risks associated with international collaboration?

Answer 8:

Complications and delays can arise for an organization in any nation working on complex systems such as those that NASA and its international partners develops. In many cases, the instruments or technologies are the first of their kind and international collaboration, with appropriate export controls, helps leverage expertise from more than one nation to advance science and resolve significant technological challenges. International partnerships also leverage capabilities and resources that might otherwise be out of reach if not for the participation of other nations on science and exploration missions. Finally, international partnerships promote broader U.S. national goals.

All NASA missions follow a rigorous development and design review cycle, regardless of whether the mission involves international partners. In cases where delays occur, NASA has instituted a variety of measures to improve performance including but not limited to increasing technical oversight, instituting independent reviews, and establishing more robust programmatic reporting requirements. These measures have been detailed in NASA policy guidance related to partnerships, such as NASA Policy Directive 1360.2, "Initiation and Development of International Cooperation in Space and Aeronautics Programs," and the NASA Space Act Agreements and Partnership Guides.

Several of these best practices are designed to minimize the inherent risks – schedule and others – associated with such partnerships. Specifically, NASA takes care to ensure that international contributions fall within the known scientific and technical capabilities as well as available funding of its cooperative partners. Further, international projects involving a commitment of NASA resources are documented in legally binding agreements intended to protect NASA's investment. To minimize complexity and misunderstandings, the division of responsibilities between NASA and its cooperating partners is clearly defined in our cooperative agreements. Finally, NASA strives to include performance milestones in our international agreements with sufficient clarity to support preparation of cost estimates, sound management planning, and efficient agreement administration.

Question 9:

What lessons learned from other NASA human spaceflight programs such as Shuttle, ISS, SLS, and Orion can be applied to the Lunar Outpost Gateway to ensure that it is developed and operated within cost estimates and on schedule?

Answer 9:

From a technical perspective, the groundwork for Gateway's capabilities is already being laid aboard the International Space Station (ISS), which provides heritage and operating experience for critical systems in areas such as environmental control and life support. Additionally, ISS is currently serving as a microgravity testbed to mature technologies for cislunar and deep space missions: a national capability that was not available during the design of the ISS. This critical work will continue throughout the operating life of the Station. The Orion crew vehicle's modern avionics, crew systems, and long-duration capability are all features that will also inform Gateway development. In addition, the Next Space Technologies for Exploration Partnerships (NextSTEP) contractors are currently developing Gateway ground prototypes and revealing new approaches to Gateway design, operations, and technology application to lower overall operational costs. All of these technology maturation activities serve to reduce risk and bring finer resolution to the Gateway functional requirements.

A number of lessons from NASA's experience with the commercial crew and cargo programs were employed to inform the acquisition strategy for the Gateway. For example, the Power and Propulsion Element (PPE), Habitation Element modules, and Logistics Elements, all will leverage commercial capabilities and plans including an extensive effort to develop a minimum set of NASA unique requirements and a common set of global interoperability standards. PPE released a draft solicitation in June, and inputs from industry will inform the final solicitation. Maximum use of mature technologies (e.g., commercial satellite technology, existing and advanced life support technologies) coupled with fixed-price, milestone-based contracts will serve to focus development efforts and minimize potential for cost, schedule, and requirements growth. This approach preserves program affordability by maintaining NASA costs targets, sharing of benefits and risks with industry, and executing development strategies that incorporate cost and schedule controls and incentives while adapting technical systems with high reliability for human spaceflight applications.

By utilizing ongoing NextSTEP studies and prototyping activities, NASA has established a robust commercial engagement campaign and integrated cost of analysis and feedback activities to keep the aerospace industrial base informed and participating in NASA's strategic planning and technology drivers for cislunar and deep space exploration capabilities. The Gateway team has issued multiple Requests For Information to the domestic aerospace community seeking insights on Gateway plans supporting cislunar economic development, technology maturation, and science utilization. These inputs are under review by the Gateway systems engineering teams to identify potential design options that meet Government, partner and commercial needs.

The Gateway acquisition strategy considers all available NASA contracting authorities to encourage responsiveness and efficiency in acquisition, including commercial service acquisitions, public-private partnerships, and traditional competitive procurements. The Gateway acquisition will benefit from lessons learned and best practices identified and refined through the successful award of the 32 NextSTEP contracts to date. Further, NASA is also proactively developing interoperability standards with domestic industry and international agencies to ensure broader opportunities are available for Gateway participation which also encourages a competitive environment to lower overall costs while enhancing cislunar capabilities for Government and commercial goals.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Stephen Jurczyk, Associate Administrator, NASA

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

Question 1:

During the hearing, I inquired about key things NASA could do to minimize cost and schedule growth. As part of my question, I also asked what trade-offs NASA makes when the agency is faced with unexpected cost growth and schedule delay. While I appreciate your addressing the first part of my question on what NASA was doing to minimize cost and schedule growth, you did not cover the issue of trade-offs, nor provide examples of successful trade-offs NASA has made. Please provide a more complete response to my question.

Answer 1:

NASA policy requires that for all applicable programs and projects required to have Key Decision Point Decision Memoranda, there be consistency between cost estimates, commitments, and budget account projections (by fiscal year) to ensure overall alignment with expected resources. During the budget formulation process, NASA assigns responsibility for managing budget accounts at the Mission Directorate level. These Control Account Managers (CAMs) strive to align resources to their top line budget control levels, even when realizing cost and schedule growth against commitments. When cost and schedule growth does occur, a Mission Directorate may elect to exercise de-scope options to stay within program commitments. If this is not a suitable option, the CAMs must propose trades within their accounts to cover the growth. In the rare scenario where the Agency believes the impacts are too severe to accept, it may explore alternatives to fund the growth outside of the account. One recent example where the trade was contained within the account occurred in reference to the InSight Mars Lander mission. The mission's cost increased from $675.1M to $828.9M when the mission's launch was delayed from March of 2016 to May of 2018. In this instance, Planetary Science was able to accommodate this growth within their existing budget level and the growth did not impact any other Themes within the Science Mission Directorate, or accounts across the Agency. NASA has not had to make trades across accounts due to cost and schedule growth on missions since the last James Webb re-baseline in 2011.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Stephen Jurczyk, Associate Administrator, NASA

Questions submitted by Chairman Brian Babin, House Committee on Science, Space, and Technology

Question 1a:

During Rep. Dunn's questioning during the hearing, you stated that you would provide the Wide Field Infrared Survey Telescope (WFIRST) cost estimate in the next couple of weeks. You also stated that NASA has been able to adjust scope, cost, and schedule estimates to stay within $3.2B.

a. Regarding the WFIRST mission scope review, what originally planned scientific instrument and spacecraft bus capabilities will no longer be included in order to stay within $3.2B?

Answer 1a:

The 2019 Budget proposes to terminate the WFIRST mission given its significant cost and higher priorities within NASA. If the mission continues to be funded, $3.2B is the target cost estimate for the Science Mission Directorate's (SMD's) contribution to the mission's estimated lifecycle cost, at a 50 percent confidence level. This cost estimate includes SMD's contribution to the associated coronagraph technology demonstration, but not what the Space Technology Mission Directorate would have contributed to the project.

A high level summary of the rescopes taken to reduce the estimated cost to SMD of WFIRST to $3.2B includes:

- Changes in the Widefield Instrument (WFI) requirements to reduce cost and cost risk, including (i) specifying performance at the focal plane level, rather than at the individual detector level, which reduces cost by decreasing the time required to manufacture a full set of flight detectors, (ii) utilizing WFI radiator thermal margin to decrease focal plane operating temperature from 100K to 95K, which reduces noise, thereby increasing detector yield and reducing cost; and (iii) descoping the interface for a contributed integral field channel (IFC), which reduces cost, given that the Canadian Space Agency was not able to make a commitment in a timely manner.
- Changes in the Coronagraph Instrument (CGI) resulting from treating it as a technology demonstration instrument to reduce cost and cost risk, including (i) removing all mission-level CGI science requirements, (ii) relaxing mission-level CGI performance

requirements to ensure healthy performance margins, informed by laboratory testing to date; (iii) reducing the coronagraph science team to level needed for technology demonstration support; (iv) replacing the CGI science operations center pipeline with a coronagraph data analysis team to meet technology demonstration requirements; (v) eliminating CGI general observer program and replaced it with a participating scientist program; (vi) eliminating several coronagraph modes which reduce the schedule by an estimated 10 weeks; (vii) deleting two mask orientations, two observing modes, and two spectral bands; (viii) reducing CGI operations to that necessary to demonstrate technology, i.e. from 12 months to 3 months; and (ix) assuming contributions of CGI hardware from international partners.

- Consolidations in the science operations center to reduce cost, including (i) reduced funding for science teams; (ii) only developing observing modes required by the dark energy and exoplanet surveys; (iii) reductions in widefield instrument science operations capability; (iv) consolidation of science center operations from Goddard Space Flight Center to Space Telescope Science Institute, and (v) assuming contribution of a pipeline from an international partner.
- Engineering trades have been made that reduce costs without significant reductions in science, including (i) payload integration flow changed to eliminate need for second instrument carrier, (ii) simplified telescope door mechanism; (iii) eliminated dedicated payload command and data handling box; (iv) eliminated high gain antenna damper; and (v) adjusted or reduced WFI, spacecraft, and observatory integration and testing timelines.

Question 1b:

What is the total amount of headquarters reserve required for WFIRST?

Answer 1b:

The 2019 Budget proposes to terminate WFIRST. If the mission were to continue to be funded, standard NASA practice is to estimate joint cost and schedule confidence levels (JCL) based on the integrated master schedule and multiple independent cost estimates developed for the preliminary design review (PDR) prior to approval to begin Phase C (Key Decision Point C).

- Once the JCL has been estimated, adequate Headquarters reserve will be identified to bring the total WFIRST budget up to a 70 percent confidence level.
- At this time (the beginning of Phase B), the mission design is not mature enough to estimate a JCL. However, based on the independent cost assessments which took place following the system requirements review (SRR) prior to approval to begin Phase B (Key Decision Point B), a range of cost for WFIRST was estimated.
- The range of costs for WFIRST is \$3.2B to \$3.8B (SMD only).
- The current estimate of the Headquarters reserves required for WFIRST is up to \$605M.

Material requested for the record on page 59, line 1371, by Representative Brooks during the June 14, 2018 hearing at which Mr. Jurczyk testified.

Answer:

NASA will be able to provide the Committee with a more specific ISS Transition Report delivery timeframe after the receipt of industry studies on ISS transition, which is slated for December 2018. The content of the studies will provide the Agency with a better understanding of industry's views about potential transition options, and this information will help inform the development of the second edition of the report.

Material requested for the record on page 61, line 1418, by Representative Brooks during the June 14, 2018 hearing at which Mr. Jurczyk testified.

Answer:

[Jurczyk: Yes, we're--like Mr. Martin said, we're--the launch services program is in the process of assessing that risk for all missions, and I can take a question for the record on that to get back with you when that assessment will be done.]

NASA's Launch Services Program (LSP) was asked in Spring 2017 by the International Space Station (ISS) program to assess a 2nd flight of a Falcon 9 Block 3 or Block 4 1st stage booster. LSP briefed the ISS program and NASA HQ on their findings and recommendations in October 2017. The summary from the LSP assessment was there was no discernable increase in risk for a Commercial Resupply Services (CRS) flight carrying cargo to the ISS through the reuse of a Falcon 9 1st stage booster as long as that booster has had only one prior flight; the trajectory was a "benign" trajectory flying to low-Earth orbit; the booster returned to a land landing; and SpaceX performed its post-flight inspection, repair and replace process. The SpaceX CRS-13 flight successfully flew on December 6th, 2017 using a previously flown 1st stage booster that met the LSP provided criteria. (LSP also conducted an assessment at the request of ISS for the SpaceX CRS-15 flight that flew successfully on June 29th, 2018.) LSP will continue to evaluate Falcon 9 reusability as necessary for appropriate future NASA missions.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6371
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July 2, 2018

Mr. Stephen Jurczyk
Associate Administrator
National Aeronautics and
Space Administration (NASA)
300 E Street SW
Washington, D.C. 20546

Dear Mr. Jurczyk,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the June 14, 2018, hearing titled, "*NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges*."

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than July 16, 2018. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than July 16, 2018.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Brian Babin

Rep. Brian Babin
Subcommittee Chairman

cc: Rep. Ami Bera
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Stephen Jurczyk, Associate Administrator, NASA

Questions submitted by Chairman Brian Babin, House Committee on Science, Space, and Technology

1. During Rep. Dunn's questioning during the hearing, you stated that you would provide the Wide Field Infrared Survey Telescope (WFIRST) cost estimate in the next couple of weeks. You also stated that NASA has been able to adjust scope, cost, and schedule estimates to stay within $3.2 billion.

    a. Regarding the WFIRST mission scope review, what originally planned scientific instrument and spacecraft bus capabilities will no longer be included in order to stay within $3.2 billion?

    b. What is the total amount of headquarters reserve required for WFIRST?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Stephen Jurczyk, Associate Administrator, NASA

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

1. After years of reporting that conditions at NASA were improving, GAO recently found that schedule delays and cost growth are now on the upswing. Were you surprised by the upswing in schedule delays and cost growth that GAO brought to light? Are both short-term and long-term changes being considered by NASA to address the problem? If so, what are some examples?

2. Recent instances have occurred where avoidable mistakes were committed by contractor personnel during fabrication, assembly, testing, and integration of spacecraft. Is there an underlying cause for these unforced errors and how can they be minimized?

3. How can NASA balance accountability and enforcement of contract provisions with the need to maintain a trusting, team-oriented relationship with its contractors and partners? Has the use of contract incentives such as award fees led to positive outcomes at NASA? If so, please provide some examples. What leverage does NASA have on a contractor when award fees are no longer available?

4. In a 2012 report, the NASA OIG stated that funding instability can lead to inefficient management practices and encouraged NASA to both increase its efforts to determine the extent to which funding instability impacts NASA projects and to clarify the cause and effect relationship between funding instability and project increases, schedule delays, and performance problems. Has NASA implemented actions responsive to the NASA OIG's concern? What are examples of actions NASA has taken or is taking?

5. Technology changes at a rapid pace and often leads to new concepts for NASA missions and spacecraft operations. Yet, current cost models used to develop cost estimates rely heavily on historical experience.
    a. To what extent are cost and schedule models keeping pace with new concepts?
    b. Is NASA supporting research and development in cost and schedule modeling? If so, provide examples of existing efforts.

6. GAO identified workforce challenges, including workforce skills and sufficiency of staffing, as an issue in its assessment of major projects. How does NASA factor workforce capabilities into its decisions on choosing whether to place mission development and management responsibilities at a Center or with a contractor?

7. How does NASA determine the level of cost and schedule reserves to be included in the estimated cost of a program and how does NASA determine how much of these reserves are allocated to the project and program?

8. Although NASA's collaboration with international partners has been critical to the success of many missions, some of these partnerships have encountered schedule delays. What are the lessons learned from instances of schedule delay with international partners? What, if any, steps can NASA take to mitigate the risks associated with international collaboration?

9. What lessons learned from other NASA human spaceflight programs such as Shuttle, ISS, SLS, and Orion can be applied to the Lunar Outpost Gateway to ensure that it is developed and operated within cost estimates and on schedule?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"NASA Cost and Schedule Overruns: Acquisition and Program Management Challenges"

Mr. Stephen Jurczyk, Associate Administrator, NASA

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

1. During the hearing, I inquired about key things NASA could do to minimize cost and schedule growth. As part of my question, I also asked what trade-offs NASA makes when the agency is faced with unexpected cost growth and schedule delay. While I appreciate your addressing the first part of my question on what NASA was doing to minimize cost and schedule growth, you did not cover the issue of trade-offs, nor provide examples of successful trade-offs NASA has made. Please provide a more complete response to my question.

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

October 10, 2018

Reply to Attn of: OLIA/2018-00388:SWQ

The Honorable Lamar Smith
Chairman
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Smith:

Enclosed is material requested for the record and responses to written questions submitted by Ranking Member Johnson resulting from the June 25, 2018 hearing entitled, ***"James Webb Space Telescope: Program Breach and its Implications."***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

cc: The Honorable Eddie Bernice Johnson, Ranking Member

Enclosure

Material requested for the record on page 84, line 1926 and 1934, by Representative Takano during the July 25, 2018 hearing at which Administrator Bridenstine testified.

Answer:

Northrop had submitted to NASA one overrun proposal since the 2011 replan. This proposal, which was received in July 2016, addressed Northrop overrun costs relative to Optical Telescope/ Integrated Science instrument (OTIS) Integration & Testing (I&T); vibration testing support; delays in the Particle Dampers; and risk reduction efforts to maintain project's critical path. The total negotiated value was $180M. Overrun proposals are not fee bearing.

On Friday, August 24, 2018, Northrop submitted a second overrun proposal for the slip to the new launch readiness date. This latest Northrop Grumman proposal is currently undergoing the customary assessment, evaluation, and contract modification process. NASA can make the final definitized amount available to the Committee when that amount has been negotiated. Again, overrun proposals are not fee bearing.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"James Webb Space Telescope: Program Breach and its Implications"

Mr. Jim Bridenstine, Administrator, NASA

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

Question 1:

The IRB found that management communication and reporting on JWST were confusing, unclear, and at times, inconsistent. More concerning is that the criticality of certain risks – red/yellow/green--were portrayed differently at various levels within the agency. How do you account for this communication problem and are you concerned that there may have been attempts to minimize certain risks on JWST?

Answer 1:

The Webb Program and Project offices are working closely together to ensure improve communication of mission status, including ensuring that assessment charts accurately communicate Webb status and risk in an appropriate manner. Differing status and risk ratings at different levels of NASA appropriately occur when there are legitimate differences in the risk posture, such as when Headquarters is holding additional reserves to mitigate a risk at the project level. In such cases, we will ensure that the differences are transparently identified and noted.

Question 1a:

Has NASA, in conjunction with its primary partners on JWST, developed a communications plan to address the IRB's recommendation on management communication? If so, have the JWST partners been provided a draft of the plan, reviewed it, and provided comments? If not, why not?

Answer 1a:

Yes, a management communication policy is being drafted and will be incorporated in the Webb Program/Project Plan as an appendix. This policy will be communicated to all applicable levels of NASA management as well as Webb partners.

Question 1b:

Is the issue the IRB raised on management communication unique to JWST or are you looking at management communication and reporting across the agency?

Answer 1b:

NASA is committed to continuous improvement in all of our missions and is evaluating the lessons learned from Webb for their broader applicability to NASA's other missions. NASA uses a series of checks and balances, including separation of programmatic and technical authorities, to enhance open communications and ensure both technical and programmatic challenges are raised to decision makers. These processes have proven to be effective in identifying issues that could impact mission success both technically and programmatically.

Question 2:

Now that the OTIS has been completed, tested, and demonstrated to meet science requirements through its testing, what are NASA and Northrop Grumman doing to ensure that its instruments and any lubricants, seals, batteries, and detectors do not degrade during the extended storage period until launch?

Answer 2:

NASA and Northrop Grumman are managing all OTIS limited life and contamination sensitive components during the extended storage period. All limited life items including lubricants, mechanisms, and motors are usage-based and do not degrade with time in the cleanroom environment. Detector life testing has demonstrated life expectancy well beyond the expected storage time and operations associated with the new launch readiness date when maintained with a dry air purge, as it is now in the clean room. Telescope optical surfaces are monitored for cleanliness and adequate controls are implemented to maintain cleanliness within prescribed limits prior to launch. OTIS does not contain any batteries.

Question 3:

What actions is NASA currently taking to ensure the security of JWST's transportation to the launch site in Kourou, French Guiana? Has NASA developed a security plan? Please provide a copy to the Committee.

Answer 3:

NASA has worked, and will continue to work with the United States Transportation Command (USTRANSCOM) to assess threats both natural (seas, weather) and otherwise leading up to and during the shipping. NASA will transport the observatory to the launch site, and will work on the details of security arrangements based on the threat analyses. Approximately one year before Webb's launch-readiness date, USTRANSCOM will perform a detailed threat assessment of transportation to the launch site, based on arrangements made with the Webb Project in 2015. Further security adjustments may be made based on that assessment.

Question 4:

How many cost overrun proposals has Northrop submitted to NASA since the original JWST replan agreement in 2011? What is the total value of those cost overrun proposals and did they include award fees?

Answer 4:

Northrop had submitted to NASA one overrun proposal since the 2011 replan. This proposal, which was received in July 2016, addressed Northrop overrun costs relative to Optical

Telescope/ Integrated Science instrument (OTIS) Integration & Testing (I&T); vibration testing support; delays in the Particle Dampers; and risk reduction efforts to maintain project's critical path. The total negotiated value was $180M. Overrun proposals are not fee bearing.

On Friday, August 24, 2018, Northrop submitted a second overrun proposal for the slip to the new launch readiness date. This latest Northrop Grumman proposal is currently undergoing the customary assessment, evaluation, and contract modification process. NASA can make the final definitized amount available to the Committee when that amount has been negotiated. Again, overrun proposals are not fee bearing.

Question 5:

During the question and answer session of the hearing on July 26, Mr. Bush commented on the benefits of having independent cost estimates as part of a contract selection process. In addition, Mr. Young noted that NASA should develop a most probable cost of a program and not rely on bid proposals from contractors in the contractor selection process. Do you agree that NASA should either obtain an independent cost estimate or develop a most probable cost for a program rather than rely on bid proposals in the selection of contractors for major projects?

Answer 5:

As part of the selection process, NASA develops Independent Government Cost Estimates (IGCEs) and probable cost estimates to assist in determining the reasonableness of contractors' proposed costs. Probable cost estimates are developed based on a cost realism analysis conducted on an offeror's bid proposal costs. IGCEs are developed based on the requirements of the Performance Work Statement (PWS) and are used to help determine the reasonableness of an offeror's bid proposal costs. IGCEs, probable cost estimates, and contractor bid proposal costs are used in conjunction with one another to determine the selection of an offeror for a major project. Use of one without the other would increase the risk of selecting a contractor whose costs are not realistic or reasonable to perform under the contract.

Question 5a:

NASA has moved its cost analysis functions to the Office of the Chief Financial Officer. How many OCFO staff are dedicated, full time, to independent program and cost analysis? What independent program and cost analysis functions do they perform?

Answer 5a:

NASA draws support for its Agency Standing Review Board (SRB) assessment process from a variety of offices. In the past year, for example, the Agency has utilized 38 unique cost and/or schedule analysts from among the following:

- 8 unique Centers (this includes HQ and JPL),
- NASA HQ Mission Directorates, and
- HQ OCFO.

To further elaborate, in October 2015, the NASA Associate Administrator realigned the Agency's independent assessment function. The Office of Evaluation/Independent Program Assessment Office (OoE/IPAO) was disbanded and the execution function of performing NASA's Standing Review Boards were delegated to the Mission Directorates (MDs) and Centers. As stated in the Associate Administrator's memorandum entitled Independent Assessment of NASA Programs and Projects, "To be clear, independent assessment of NASA Programs and Projects will continue. Mission Directorates in coordination with executing Centers will be responsible for selecting the Standing Review Board (SRB) chair and recruiting the Agency's expertise to populate the board and providing that to the Decision Authority, the NASA Associate Administrator." Additionally, the other functioning office within OoE, the Cost Analysis Division (CAD), transitioned to the Office of the Chief Financial Officer.

Further guidance was released in 2016 by the NASA AA describing the principles of NASA's new independent assessment construct. The programmatic support (cost and schedule analysis) provided for the Agency's independent assessments (Standing Review Boards - SRBs) is now provided in a decentralized fashion from HQ and all field Centers.

HQ OCFO has a team that oversees all of legacy-CAD responsibilities as well as the stewardship of ensuring that programmatic support is provided to independent assessment (IA) in a robust and consistent way. Specifically with regards to independent assessment, the team provides roughly one FTE, plus additional WYE, support to the IA process and implementation. HQ OCFO works with Center and MDs to ensure that competent and independent analysts are available for the anticipated review manifest. By definition of the new IA construct, cost and schedule analysts are not working independent assessment full time.

The HQ OCFO resources discussed above only refer to dedicated analysts for IA in support of Agency SRB reviews. HQ OCFO resources supporting broader cost, schedule, and EVM implementation is approximately similar to levels before cost estimating capability moved to OCFO (~7 FTEs with additional WYE support). HQ OCFO also provides IA in other forums.

OCFO ensures that program assessments are done in a consistent, transparent, and robust fashion.

Question 6:

During the question and answer portion of the hearing, Mr. Young stated that the Goddard Space Flight Center (GSFC) Director should be totally responsible for JWST and that the GSFC Project Manager should report to the Center Director. Mr. Young also said that, at the Program level, the Associate Administrator for the Science Mission (SMD) Directorate should have responsibility for JWST at NASA Headquarters and that the GSFC Director should report to the SMD Associate Administrator. Do you agree with the IRB's recommendation of this management structure? If so, what is being done to address the IRB's recommendation?

Answer 6:

The Webb Program and Project understand the fundamental concern of the IRB and are developing a plan to ensure that the organizational responsibilities and reporting relationships are well understood throughout the Webb program.

Question 7:

During the hearing, you discussed NASA's Pathways program as a means of increasing the number of younger employees in the NASA workforce and preparing for the anticipated increase in the retirement of experienced NASA workers. How is NASA measuring the effectiveness of the Pathways program in attracting the skills needed to serve NASA mission programs over the coming decades?

Answer 7:

The conversion rate demonstrates how we are meeting the skill needs for the future with talented students, so we consider 60-70 percent conversion rate to be a measure of success for NASA's Pathways Intern Program.

Additionally, NASA is in the process of implementing an Agencywide survey of hiring managers to determine the quality of new hires. Although there is no data to report yet on the Agency survey, we will begin surveying hiring managers whose new employees began working on and after July 1, 2018.

Question 7a:

How is NASA providing hands-on skills to new professionals that will enable them to have the direct engineering and technical skills commensurate with the complexity of the programs that NASA is undertaking?

Answer 7a:

As part of our annual workforce planning process, we identify where the hands-on work is located. We begin by assigning entry level professionals to small hands-on design and development projects and give them larger projects and greater responsibility as they increase their competence.

For example, our Space Technology Mission Directorate's Early Career Initiative (ECI) invigorates NASA's technological base and improves current best practices by partnering early career NASA leaders with world class external innovators. ECI enables early career technologists to lead hands-on technology development projects to deliver transformative space technologies while teaming with external innovators and exploring agile development approaches from other research and development organizations. Our Suborbital projects (balloons and sounding rockets) also provide opportunities for hands-on work for early career scientists in civil service and the private sector.

Not all hands-on skills are gained as NASA civil servants. NASA also obtains hands-on skills through hiring from outside the Agency at the mid-career level.

Results from the 2018 Federal Employee Viewpoint Survey (the most recent available) show that 75 percent of NASA employees agree or strongly agree that their talents are used well in the workplace, an indication that they are receiving the engineering and technical skills at NASA that are directly applicable to the Agency's programs.

Question 8a:

The Government Accountability Office (GAO) reviewed NASA's use of award fees for the JWST on two occasions. In the first instance, GAO found in its December 2014 report that evaluation criteria were not specified for the final evaluation of total contract performance in the project's performance evaluation plans. In the second instance, in December 2015, GAO found that the award fee Northrop Grumman received was not reduced despite workforce size issues.

a. In the time period in which GAO made its reviews, what was the level of involvement by the Science Mission Directorate and Administrator's Office in helping the project (a) establish the amount of award fee earned by Northrop Grumman and (b) ensure that the award fee is based on meeting agreed-to criteria?

Answer 8a:

Award fee for contracts is determined by a Fee Determining Official at the implementing center (in Webb's case, Goddard Space Flight Center). The Science Mission Directorate and the Administrator's Office can provide input to the award fee evaluation process. The award fee process is designed to ensure assessment of the contractor's performance by individuals directly working with the contractor. This ensures that effective and specific task related feedback is given to the contractor on their performance. Once performance is assessed by those who work directly with the contractor, a recommendation for the award fee rating is presented to the Fee Determination Official, and the Science Mission Directorate is informed of award fee determinations.

Question 8b:

Did the level of involvement by the Science Mission Directorate and the Administrator's Office change in the period subsequent to GAO's December 2015 review and just prior to the IRB report? If so, in what ways did it change?

Answer 8b:

There was no change in level of involvement by the Science Mission Directorate and the Administrator's Office after the 2015 review.

Question 8c:

Will the level of involvement change subsequent to the IRB's recent findings and recommendations? If so, in what ways will it change?

Answer 8c:

Improved communication at all levels of NASA senior management has been implemented. The attendance list of several key existing meetings has been expanded to ensure that senior NASA management is hearing project status and issues at the same time. In addition, the monthly SMD flight project review (FPR) and GSFC monthly status review (MSR) has been combined into a single monthly status meeting and attendance expanded to include the Associate Administrator (AA) for Science Mission Directorate (SMD) and the SMD Deputy AA. The SMD AA is now also invited to the project/program tag up on a monthly basis to actively participate in Webb status and issues discussions.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
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August 22, 2018

Hon. Jim Bridenstine
Administrator
National Aeronautics
and Space Administration (NASA)
300 E Street SW
Washington, D.C. 20546

Dear Mr. Bridenstine,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the July 25-26, 2018, hearing titled, "*James Webb Space Telescope: Program Breach and its Implications*."

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than September 5, 2018. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than September 5, 2018.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Lamar Smith

Lamar Smith
Chairman

cc: Eddie Bernice Johnson
Ranking Member

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"James Webb Space Telescope: Program Breach and its Implications"

Mr. Jim Bridenstine, Administrator, NASA

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

1. The IRB found that management communication and reporting on JWST were confusing, unclear, and at times, inconsistent. More concerning is that the criticality of certain risks --red/yellow/green--were portrayed differently at various levels within the agency. How do you account for this communication problem and are you concerned that there may have been attempts to minimize certain risks on JWST?
    a. Has NASA, in conjunction with its primary partners on JWST, developed a communications plan to address the IRB's recommendation on management communication? If so, have the JWST partners been provided a draft of the plan, reviewed it, and provided comments? If not, why not?
    b. Is the issue the IRB raised on management communication unique to JWST or are you looking at management communication and reporting across the agency?
2. Now that the OTIS has been completed, tested, and demonstrated to meet science requirements through its testing, what are NASA and Northrop Grumman doing to ensure that its instruments and any lubricants, seals, batteries, and detectors do not degrade during the extended storage period until launch?
3. What actions is NASA currently taking to ensure the security of JWST's transportation to the launch site in Kourou, French Guiana? Has NASA developed a security plan? Please provide a copy to the Committee.
4. How many cost overrun proposals has Northrop submitted to NASA since the original JWST replan agreement in 2011? What is the total value of those cost overrun proposals and did they include award fees?
5. During the question and answer session of the hearing on July 26, Mr. Bush commented on the benefits of having independent cost estimates as part of a contract selection process. In addition, Mr. Young noted that NASA should develop a most probable cost of a program and not rely on bid proposals from contractors in the contractor selection process. Do you agree that NASA should either obtain an independent cost estimate or develop a most probable cost for a program rather than rely on bid proposals in the selection of contractors for major projects?

a. NASA has moved its cost analysis functions to the Office of the Chief Financial Officer. How many OCFO staff are dedicated, full time, to independent program and cost analysis? What independent program and cost analysis functions do they perform?

6. During the question and answer portion of the hearing, Mr. Young stated that the Goddard Space Flight Center (GSFC) Director should be totally responsible for JWST and that the GSFC Project Manager should report to the Center Director. Mr. Young also said that, at the Program level, the Associate Administrator for the Science Mission (SMD) Directorate should have responsibility for JWST at NASA Headquarters and that the GSFC Director should report to the SMD Associate Administrator. Do you agree with the IRB's recommendation of this management structure? If so, what is being done to address the IRB's recommendation?

7. During the question and answer portion of the hearing, Mr. Young stated that the Goddard Space Flight Center (GSFC) Director should be totally responsible for JWST and that the GSFC Project Manager should report to the Center Director. Mr. Young also said that, at the Program level, the Associate Administrator for the Science Mission (SMD) Directorate should have responsibility for JWST at NASA Headquarters and that the GSFC Director should report to the SMD Associate Administrator. Do you agree with the IRB's recommendation of this management structure? If so, what is being done to address the IRB's recommendation?

8. During the hearing, you discussed NASA's Pathways program as a means of increasing the number of younger employees in the NASA workforce and preparing for the anticipated increase in the retirement of experienced NASA workers. How is NASA measuring the effectiveness of the Pathways program in attracting the skills needed to serve NASA mission programs over the coming decades?

   a. How is NASA providing hands-on skills to new professionals that will enable them to have the direct engineering and technical skills commensurate with the complexity of the programs that NASA is undertaking?

9. The Government Accountability Office (GAO) reviewed NASA's use of award fees for the JWST on two occasions. In the first instance, GAO found in its December 2014 report that evaluation criteria were not specified for the final evaluation of total contract performance in the project's performance evaluation plans. In the second instance, in December 2015, GAO found that the award fee Northrop Grumman received was not reduced despite workforce size issues.

a. In the time period in which GAO made its reviews, what was the level of involvement by the Science Mission Directorate and Administrator's Office in helping the project (a) establish the amount of award fee earned by Northrop Grumman and (b) ensure that the award fee is based on meeting agreed-to criteria?

b. Did the level of involvement by the Science Mission Directorate and the Administrator's Office change in the period subsequent to GAO's December 2015 review and just prior to the IRB report? If so, in what ways did it change?

c. Will the level of involvement change subsequent to the IRB's recent findings and recommendations? If so, in what ways will it change?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

October 12, 2018

Reply to Attn of: OLIA/2018-00390:SWQ

The Honorable Lamar Smith
Chairman
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Smith:

Enclosed are responses to written questions submitted by you, Ranking Member Johnson and Representative Rosen, resulting from the June 24, 2018, hearing entitled, ***"Urban Air Mobility – Are Flying Cars Ready for Take-Off?"***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

cc: The Honorable Eddie Bernice Johnson, Ranking Member

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Urban Air Mobility – Are Flying Cars Ready for Take-Off?"

Dr. Jaiwon Shin, Associate Administrator, Aeronautics and Research Mission Directorate, NASA

Questions submitted by Chairman Lamar Smith, House Committee on Science, Space, and Technology

Question 1:

There are a series of challenges that need to be overcome before UAM can come to fruition. In your opinion, what are the top two most significant technology and regulatory challenges that need to be overcome to make UAM a reality?

Answer 1:

Urban air mobility (UAM) system-level considerations require many individual technologies to coalesce. From a technical perspective, this includes technologies to provide safe and efficient air traffic management (ATM) for a large number of vehicles, and to find ways to ensure safety of passengers and people on the ground in contingency situations. Challenges around developing, testing, and certifying the necessary ATM technologies and contingency management technologies will both require levels of automation that do not have a precedent for certification and also operational approval. From the regulatory perspective, the challenges will be developing approaches and sufficient data to get these novel vehicles' configurations certified (i.e., assuring that they are safe) and obtaining an approval for operations in and around dense urban areas. While NASA is not heavily involved in the area of cybersecurity, given the nature of UAM this could be a challenging area. While the system needs to be interconnected and have the ability to easily share data among the users, it must be secure from outside tampering. The FAA and other agencies are working on the cybersecurity issue. As the UAM community integrates IT into the systems, improving the interconnectivity of the parts, this will become more and more of an issue to ensure the IT systems can be integrated into a community wide ecosystem. There will also likely be significant regulatory challenges in developing noise standards and ensuring the public accepts noise profiles created by UAM acitivities.

Question 2:

What roles will be played by the private and public (federal, state, local) sector to advance UAM transportation? How will the various participants in the UAM community collaborate on their roles to address issues as disparate as safety, environment, cybersecurity, zoning etc.?

Answer 2:

This is a nascent industry, and roles are still being developed and assessed. Industry is working diligently to bring first generation vehicles to market. Federal agencies need to develop appropriate regulations, policies and processes for vehicle and operational certification, and also development, deployment and/or oversight of essential ATM management systems (i.e. UTM). The public and private sectors will be required to work together to ensure the entire system meets the safety expectations of the flying public. This will include many topics such as significant technology development, operational R&D, standards development, Verification &Validation (V&V) needs, and cybersecurity requirements. From the local perspective, issues such as zoning, noise, privacy, .land rights, and other considerations will need to be addressed to enable the full UAM vision.

The various participants are currently collaborating informally through conferences, workshops, forums, standards bodies, and business-developed consortiums. In the future it is envisioned that robust public-private partnerships may contribute to fully coordinate and approve UAM operations.

Question 3:

There has been extensive research conducted in battery technology aimed at surface transportation. Are the battery needs of aviation different from surface transportation, and would it be beneficial to consider these issues in research programs?

Answer 3:

Battery needs for aviation are quite different, and more challenging, than requirements for surface transportation. For example, batteries for aviation propulsion systems need to deliver higher power at significantly lower weight. These systems must also include redundancies and other unique safety features not needed in surface transportation. Requirements for. air vehicle weight limitations, life cycles, power needs, operating temperatures, and safety/reliability are all significantly different than surface transportation needs. While NASA ARMD has strong research efforts underway in UAM, electric propulsion and hybrid- electric propulsion,. NASA believes it is most appropriate to leverage advances in battery technologies through research being conducted by other entities in government, academia and industry, as opposed to initiating our own research in this field.

Question 4:

It is a central mission of the National Institute of Standards and Technology (NIST) to develop standards in just about everything. What role has NIST played thus far in the UAM discussion? As the technology progresses and discussions turn to standardizing various aspects of the UAM concept, how might an agency like NIST contribute?

Answer 4:

NASA has been regularly coordinating with NIST through both the Cyber Physical Systems (CPS) Interagency Work Group (IWG) and through the Global Smart Cities Initiative. Key technical interchanges have revolved around frameworks and standards for supporting autonomous systems services that would help enable intelligent vertiports and autonomous, on-demand vehicles and systems. NASA may not be fully aware of the entire set of NIST interactions, but many standards groups will be required to develop UAM standards .. NIST will likely play a significant role in this process.

Question 5:

Safety concerns relative to VTOLs fall under two general buckets: safety of passengers on the vehicle and safety of the public outside the vehicle in the event of a catastrophe. How might issues of liability be handled when something goes wrong and people perish?

Answer 5:

This issue is outside of NASA's scope and mission.

Question 6:

As our efforts to develop UAM progresses, where do we expect to see delays – in the development of technology, or in the ability of the public sector (federal, state, local governments) to keep up with innovation by implementing the relevant polices and regulations in a timely manner?

Answer 6:

It is difficult to characterize the speed of likely progress in evolution of UAM due to the nascent nature of the UAM industry. While technologies to enable UAM are converging, there are many individual technology and integration issues that are not yet solved including vehicle configuration, automation, batteries, operational issues and systems integration issues. These types of challenges are typical to complex technology development and systems integration. There are similar significant policy and regulatory challenges to adoption of UAM. It is difficult to predict how quickly these challenges will be overcome. However, a successful UAM industry will require advances in all of these areas in order for a safe system to be accepted by the broader public.

Question 7:

Besides NASA and FAA, what other federal agencies have a role to play in the design, development or rollout of VTOLs and the UAM system, and what are their roles?

Answer 7:

Private industry around the world is making heavy investment in the design and development of electric VTOLs with diverse design concepts. Therefore, NASA believes its role should be leading the community by addressing system-wide issues such as safety and community noise. NASA is also working with the FAA to develop efficient and effective ways of certifying these new air vehicles. Beyond the vehicle development, NASA and FAA are collaborating to develop a new way to manage high-volume traffic at low altitude. In addition to the air vehicle and air traffic management development, many federal, state and local governments would have important roles to address other key areas such as cybersecurity, infrastructure for vertiports and charging stations, power grid management, and accurate aviation weather service.

Question 8:

With regard to developing VTOLs and the UAM system, is there any international coordination or collaboration, either with other governments or with companies registered in other nations? How do we walk the fine line between protecting sensitive information or trade secrets, yet still work with foreign counterparts to learn from and teach each other?

Answer 8:

As a founding member of The International Forum of Aviation Research (IFAR), NASA is working with IFAR-represented countries on pre-competitive and common technologies and challenges that member governments can work together to "raise the water level for all." IFAR aims to connect research organizations worldwide, to enable the information exchange and communication on aviation research activities and to develop among its members a shared understanding on challenges faced by the global aviation research community. IFAR members are government-funded national R&D organizations conducting aeronautics research, or universities representing the countries that do not have national aeronautics laboratories. By focusing on. pre-competitive and common technologies, NASA continues to walk the fine line between protecting sensitive information including trade secrets, while working with members of the IFAR community. In general, NASA works with the international community in areas such as information related to setting international standards and recommended practices for aviation safety and cross-border operations, but not in areas such as research into design tools or specific technologies that may have a competitive impact. NASA has engaged with IFAR members on some limited aspects of UTM, and similarly is considering opportunities for discussions with IFAR members about UAM. NASA Aeronautics typically does not work directly with non-U.S. companies; any such partnerships would be considered on a case-by-case basis in accordance with NASA policies.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Urban Air Mobility – Are Flying Cars Ready for Take-Off?"

Dr. Jaiwon Shin, Associate Administrator, Aeronautics and Research Mission Directorate, NASA

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

Question 1a:

In his prepared opening statement, Dr. Clarke stated that the four most urgent and most difficult research projects identified by the 2014 National Academies Panel on autonomy are relevant to the realization of UAM. He also stated that while NASA had started research in each of these areas, progress had been slow and needed to be accelerated.

a. Do you agree with his characterization of NASA's level of activity?

Answer 1a:

We appreciate Dr. Clarke's contributions to the publication of the National Academies Autonomy study, which is a service to the whole community. NASA believes that we have a unique role making high impact contributions to the emerging urban air mobility (UAM) community by addressing system-wide barriers. One such example is NASA's focus on research for developing technologies, data, and methods for establishing new safety standards and certification methods. If these barriers are not addressed, there will be no realization of a UAM market of any kind. Industry, on its own, is making significant investments for vehicle designs and developments with various approaches to more and eventually fully autonomous operations of UAM vehicles. NASA and industry will continue to work together, leveraging each other's investment and expertise without duplicating efforts to advance the state of autonomy research. NASA develops its research priorities and deliverables in close coordination with the relevant safety, operational, and regulatory components of the Federal Aviation Administration. Because NASA is not a regulatory agency, accelerating NASA research in an uncoordinated manner will not effectively reduce the barriers to realizing UAM.

Question 1b:

If you agree with the need for increased activity, how and when could NASA begin to accelerate its efforts? If you do not agree, why not?

Answer 1b:

NASA agrees with the need for increasing activity in autonomy research across the aviation community, including both vehicles and air traffic management, and is adjusting our portfolio accordingly. NASA introduced an autonomy thrust in our 2015 Strategic Implementation Plan, but had been working on autonomy related activities for many years prior. Specifically, NASA's Unmanned Aircraft Systems (UAS) Integration in the National Airspace (NAS) project has been working the autonomy thrust providing significant benefit to the UAS community through developing broadly applicable "detect and avoid" and "command and control" technologies. NASA has also led a national effort in development of a UAS Traffic Management (UTM) technology that will be leveraged to automate air traffic management of UAS in airspace that is not typically required to be actively managed by the FAA.

While the levels of autonomy required for introduction of Urban Air Mobility (UAM) may be minimal, NASA does agree that autonomous technologies are essential to enable the full benefit of UAM. In the past two years, NASA has increased the focus on autonomy research. NASA is in the planning phase for a focused autonomy project designed to provide even more benefit towards UAM. NASA is currently working with a broad industry community defining additional autonomy research efforts as a new set of non-traditional aviation companies (e.g. google, amazon, intel, etc.) with significant experience in autonomy, but minimal experience in aviation, progresses towards implementation of aviation products.

The envisioned use cases of both UAM and low altitude UAS need the vehicles to operate in the same airspace as current manned and commercial aviation. NASA's UTM and Air Traffic Management-Exploration (ATM-X) projects will research how to enable the seamless, safe and efficient integration of all users of the airspace. The federated air traffic management architecture of the UTM project will be leveraged to establish a federated future air transportation management system that is scalable from the current manned daily operations of tens of thousands of vehicles to the envisioned manned or unmanned millions of daily vehicle operations through introduction of UAM and low-altitude UAS. NASA's research will seek to enable equitable access to the airspace for all users, vehicles, and missions by developing and demonstrating a new service-based paradigm leveraging UTM principles using a build and test approach to provide:

- Seamless access to the airspace for users and missions—both on-demand (UAM, UAS) and scheduled (supersonic, ultra-high altitude, and space);
- Scalability for increased demand across users and missions;
- Flexibility whenever possible and structure only when necessary;
- Collaboration through integrated information exchange;
- Resilience to uncertainty, degradation, and disruptions; and
- Increased availability and use of user and third-party services.

Furthermore, NASA's System-Wide Safety (SWS) project will enable data-driven, prognostic in-time system-wide safety for diverse and more highly automated airspace operations. The project's goals are to explore, discover, and understand the impact on safety of growing complexity introduced by modernization aimed at improving the efficiency of flight, the access to airspace, and/or the expansion of services provided by air vehicles. The SWS project will:

- Develop and demonstrate integrated risk assessment capabilities to monitor terminal area operations based on data analytics and predictive models;
- Develop and demonstrate integrated dependable monitoring, assessment, and mitigation capabilities for safety-critical risks to low-altitude urban beyond visual line-of-sight (BVLOS) small UAS (sUAS) operations; and

- Develop and demonstrate cost-efficient Validation and Verification (V&V) tools, methods, and guidance that provide justifiable confidence in safety claims for designs of complex, safety critical Air Traffic Management (ATM) and avionics systems.

Many players in this emerging UAM industry think that vertical lift vehicle capability combined with autonomy are key to realizing the potential business case of new missions and new markets. NASA is proactively examining what and how our strong vertical lift expertise can make timely and compelling impact to major barriers to the UAM market such as noise and safety.

Question 1c:

Would this UAM research require additional funding? If so, when could we expect to see a budget request?

Answer 1c:

NASA is engaging with a broad range of stakeholders to assess the appropriate levels and areas of research where NASA can have the greatest impact in the emerging UAM market. This emerging market presents a significant potential for the U.S. economy and the government must work together with industry to ensure U.S. global leadership. NASA envisions maintaining an important role in supporting the UAM sector. NASA research objectives and associated resource requirements are documented in the President's annual budget requests.

Question 2:

Last year, NASA contracted with two consulting firms to conduct a market analysis of UAM to help the agency decide how to deploy resources and develop an appropriate research agenda. Is that analysis complete and if so, to what extent has NASA incorporated those results into its UAM research strategy?

Answer 2:

The UAM market studies and analysis that NASA funded are not yet complete, however they are being factored in to our decision-making processes. We have formed a UAM Coordination and Assessment Team (UCAT) to supply cohesive, well-coordinated thinking across various ARMD projects that need to contribute to UAM research. The two market studies results are used with the coordinated efforts by UCAT. We have disseminated preliminary study results to researchers and project managers in relevant projects who are using them as guidance. NASA's UAM strategy efforts are using these inputs to help determine and prioritize critical barriers that need to be addressed by NASA and the broader community. NASA has also leveraged these studies to document critical operational concepts that our research portfolio will help enable, and to understand and begin coordination with the entire ecosystem of UAM-related partners (e.g., other government agencies, appropriate standards orgs, infrastructure developers, local regulators, Smart Cities, etc.).

Question 3a:

In your prepared statement, you state that communities will not accept noise that significantly exceeds background noise levels and that crafting acceptable noise standards will require understanding community response to different noise signatures.

a. Can you suggest a way by which aircraft noise reduction technology and operational mitigation procedures can be evaluated by communities before UAM operations are initiated?

Answer 3a:

NASA ARMD is currently focusing on research and is drafting a Technical Challenge area that targets the development of methods and tools to assess the noise impact on the community caused by operations of a UAM fleet. As part of this work, trajectory (flight path) optimization will be evaluated as a means to mitigate the noise from these vehicles as perceived on the ground. The methodology and resulting tool are expected to be used by operators, municipal planners, and regulatory agencies when they are completed. The tool will be based on modifications to the commonly used FAA Aviation Environmental Design Tool (AEDT). Additionally, NASA is considering opportunities for organizing flight demonstrations to evaluate noise impacts, in which industry could "try out" their vehicles and assess their performance in a relevant environment.

Question 3b:

How can better modeling and simulation tools enhance the ability to predict the noise level from different concepts?

Answer 3b:

NASA is currently considering a Technical Challenge research area that will improve the high-fidelity modeling of multi-rotor, variable rpm control UAM configurations. The focus is to develop an essential capability to model complex and unusual configurations in a way that accurately calculates the noise from the multiple rotating systems, and the noise generated by the interaction with the airframe that is generally missing from current modeling tools.

There is a wide range of UAM vehicle concepts. Noise generation mechanisms will likely differ from one to another. Experimentally validated and robust modeling and simulation tools will allow vehicle manufacturers to develop effective noise mitigation technology, including operations. Further, tools that are applicable across a wide range of vehicle architectures will allow trade studies to be performed with reduced uncertainty.

Question 4:

Over the last several months this Committee has been examining the state of artificial intelligence and machine learning technologies and their potential benefits for many industries. How will machine learning affect development of UAM? What machine learning and data analysis tools is NASA researching that relate to UAM?

Answer 4:

NASA believes that machine learning can have a dramatic influence on the long-term success of UAM. While machine learning is likely not a requirement for the initial and intermediate timeframes for UAM, there is potential for a dramatic impact on the efficiency of the system as the industry reaches its mature state. The possibility of using machine learning to understand and predict localized weather in urban environments could play a critical role in UAM. As machine learning matures, it may also be able to handle critical functions that pilots today deal with intuitively, such as responding to an off-nominal scenario and then efficiently resolving the problem and optimizing the approach to return back to the original mission for the system.

Question 5a:

According to the FAA, there are approximately 5,000 aircraft in the sky at any time and more than 42,000 flights daily handled by the FAA. I understand that UAM vehicles will be operating at altitudes far below commercial aircraft.

a. How would integrating commercial traffic management and UAM traffic management make air travel safer?

Answer 5a:

Critical elements of aviation safety are situational awareness and separation assurance. A safe National Airspace System must consider all elements, and all aircraft, in order to ensure a truly safe system. The United States' current air traffic management (ATM) system is the safest in the world, but will require coordination and integration with an Unmanned aircraft system Traffic Management (UTM) system in situations where small UAS (sUAS) and urban passenger transport vehicles must interface. NASA and the FAA are currently working the integration of current ATM and future UTM systems through programs such as the FAA's Low Altitude Authorization and Notification Capability (LAANC). The UTM allows for multiple operators to share operational intent with each other through predefined data exchange protocols. Such a "share and care" environment gives complete situational awareness to all sUAS operators so that each sUAS operator can plan, schedule, fly, and track their operation in a safe manner without interfering with other operators. Further, the FAA can add real-time restrictions for safety and security reasons.

The envisioned use cases of both Urban Air Mobility (UAM) and low-altitude sUAS require the vehicles to operate in the same airspace as current manned and commercial aviation. NASA's

UTM and Air Traffic Management-Exploration (ATM-X) projects are researching how to enable seamless, safe and efficient integration of all users of the airspace. The federated air traffic management architecture of the UTM project will be leveraged to establish a federated future air transportation management system that is scalable from the current manned daily operations of tens-of-thousands vehicles, to the envisioned manned and unmanned daily operations of millions of vehicles after the introduction of UAM and low-altitude UAS. NASA seeks to enable equitable access to the airspace for all users, vehicles, and missions by developing and demonstrating a new service-based paradigm leveraging UTM principles using the build-and-test approach to provide:

- Seamless access to the airspace for users and missions — both on-demand (UAM, UAS) and scheduled (supersonic, ultra-high altitude, and space);
- Scalability for increased demand across users and missions;
- Flexibility whenever possible and structure only when necessary;
- Collaboration through integrated information exchange;
- Resilience to uncertainty, degradation, and disruptions; and
- Increased availability and use of user and third-party services.

Furthermore, NASA's System-Wide Safety (SWS) project will enable data-driven, prognostic in-time system-wide safety for diverse and more highly automated airspace operations. The project's goals are to explore, discover, and understand the impact on safety of growing complexity introduced by modernization aimed at improving the efficiency of flight, the access to airspace, and/or the expansion of services provided by air vehicles. The SWS project will:

- Develop and demonstrate integrated risk assessment capabilities to monitor terminal area operations based on data analytics and predictive models;
- Develop and demonstrate integrated dependable monitoring, assessment, and mitigation capabilities for safety-critical risks to low-altitude urban beyond visual line-of-sight (BVLOS) sUAS operations; and
- Develop and demonstrate cost-efficient Validation and Verification (V&V) tools, methods, and guidance that provide justifiable confidence in safety claims for designs of complex safety critical Air Traffic Management (ATM) and avionics systems.

Question 5b:

Can you expand on NASA's research related to detect and avoid and communication requirements for unmanned aircraft systems and its potential applicability to UAM vehicles?

Answer 5b:

NASA has been working Detect and Avoid (DAA) and Command and Control (C2) through both the UAS Integration in the NAS (UAS-NAS) and UAS Traffic Management (UTM) Projects. From the UAS-NAS perspective, research has been baselined as part of consensus standards developed in partnership with the Radio Technical Commission for Aeronautics (RTCA). From the UTM perspective, utilization of DAA and C2 technologies have been tested as part of the UTM national campaign demonstrations, UTM Pilot Program (UPP), and Integration Pilot Program (IPP). While all variants of these technologies are relevant to UAM, all also have additional research that needs to be conducted to understand direct applicability to the infant

UAM concepts of operations. For instance, sensors hosted on-board UAS are designed to specific performance capabilities to detect aircraft specific to that UAS's operating environment. A scaled urban environment would require aircraft to operate in significantly more dense operating environments. While there are no specific limitations of the technology that would make the technology irrelevant, many of the design parameters would need to be modified, at minimum, to enable the same types of operation in dense urban environments transporting passengers.

Question 6:

NASA's Aeronautics Research Mission Directorate has a critical role in assisting industry in their development of UAM vehicles and operations. NASA provides research results, tools and guidance to its industry partners for safety verification and validation activities. Unique facilities are available to partners under Space Act Agreements. What additional facilities, infrastructure, staff or tools are necessary for NASA to maintain U.S. leadership in UAM research?

Answer 6:

NASA's workforce, facilities and infrastructure have long been critical assets to the nation. As currently envisioned, UAM presents significant new challenges to the aviation industry, and NASA has already been exploring existing and new capabilities necessary to enable to the short and long-term UAM vision. Under the UAS integration in the NAS (UAS-NAS) and UAS Traffic Management (UTM) projects, NASA has spent significant time and money developing state-of-the-art capabilities for research on air traffic management, fast-time simulation, and other modeling and simulation capabilities. There are also several critical safety related tools developed by NASA that are essential to ensuring the nation is providing a transportation system that is acceptable to the public, while also providing the ability to ensure the system is becoming increasingly safe. These tools and capabilities will need to be further developed to address the significant challenges relevant to optimizing high-density urban operations.

NASA ground test infrastructure such as wind tunnels and acoustic facilities can be used to test and assess UAM concepts and technologies. These capabilities will need to be assessed to identify whether they need to be modified to meet the needs of new and novel UAM vehicle configurations.

NASA is planning to leverage restricted airspace at the NASA Armstrong Flight Research Center and adjacent Edwards Air Force Base for initial UAM flight testing, but NASA facilities will not likely satisfy the broader UAM community testing needs in the coming decade. Appropriate test sites and ranges beyond those of NASA will be critical to the enabling of the UAM industry. The FAA UAS test sites have been instrumental in progressing UAS integration, but must be accepted by industry and developed as part of a broader UAM-wide strategy to maximize their benefit. UAM proving grounds will need to be developed for both rural and urban environments, have robust communication environments, incorporate significant instrumentation upgrades, and many other costly developmental considerations.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Urban Air Mobility – Are Flying Cars Ready for Take-Off?"

Dr. Jaiwon Shin, Associate Administrator, Aeronautics and Research Mission Directorate, NASA

Questions submitted by Representative Jacky Rosen, House Committee on Science, Space, and Technology

Question 1:

As the urban air mobility (UAM) industry continues to develop vehicles, it is imperative that we begin addressing safety and management issues. Congress, FAA, NASA, local jurisdictions, and industry will need to work together to answer a multitude of questions, including: who will police the skies or respond to potential accidents? Who will be liable? How will jurisdiction of physical airspace be divided?

Answer 1:

These questions are outside of NASA's scope and mission, and are best addressed by other agencies.

Question 1a:

Can you address these questions and offer your thoughts as to how we tackle them?

Answer 1a:

These questions are outside of NASA's scope and mission, and are best addressed by other agencies.

Question 1b:

The FAA has "No Drone Zones" throughout the country and over some U.S. military facilities and airports – restricting unmanned aircraft flight. I represent a Congressional District that borders Las Vegas' McCarran International Airport, one of the busiest airports in the country. We are also less than twenty miles from Nellis Air Force Base and just over fifty miles from the Nevada Test and Training Range, which provides the largest air and ground military training space in the contiguous U.S., without interference from commercial aircraft. What will happen if UAM vehicles with passengers fly into this restricted airspace?

Answer 1b:

These questions are outside of NASA's scope and mission, and are best addressed by other agencies.

Question 2a:

I know that unmanned aircraft systems traffic management, or UTM, is something NASA has been working on quite extensively.

a. What can you tell us about the progress or expected results of NASA's research with UTM and UAM?

Answer 2a:

The Unmanned aircraft system Traffic Management (UTM) project established a set of four Technical Capability Level (TCL) demonstrations, each increasing its level of maturity, technical capability, and complexity of operations. To date, NASA has completed TCLs 1 through 3.

TCL1 demonstrated the concept for management of airspace in lower-risk environments of uninhabited areas and multiple visual line-of-sight (VLOS) unmanned aircraft systems (UAS) operations. The demonstrations and flight trials were conducted in Crows Landing, CA, and six FAA UAS test sites with 19 industry partners in August 2015 and May 2016. The results validated a cloud-based service oriented architecture and defined requirements for enabling low-altitude UAS operations in unpopulated areas with VLOS operations.

TCL2 demonstrated the complexity of multiple beyond visual line-of-sight (BVLOS) UAS operations in lower risk environments of sparsely populated areas. The demonstrations and flight trials were conducted at the Reno-Stead airport, NV and six FAA UAS test sites with 42 industry partners in October 2016 and June 2017. The results demonstrated information sharing between operators and supplemental service providers, and established the federated third party service model.

TCL3 demonstrated technology enablers to address challenges presented by multiple BVLOS UAS operations over moderately populated areas and near airports. The demonstrations and flight trials were conducted at six FAA UAS test sites with 34 industry participants during March-June 2018. The results demonstrated enabling technologies for detect and avoid, communication and navigation, and data exchange between service providers.

TCL4 is currently in the planning stage to demonstrate complex operations in highly populated areas and large-scale contingency management during the summer of 2019. The UAS test sites and industry participants are to be determined upon evaluation of the solicitation proposals. The results will determine understanding of the UTM operational concept, vehicle technologies, and data exchanges for nominal and contingency operations to safely fly in the vicinity of large structures and highly populated areas.

NASA and FAA have efficiently and closely engaged through the NASA/FAA UTM Research Transition Team (RTT) in defining the NASA-needed algorithms, research platforms, prototypes, and data that NASA must deliver to the FAA to enable their development of requirements, standards, and certifications. The UTM RTT through its four working groups --

Concepts and Use Cases, Data and Information Exchange, Sense and Avoid, and Communications and Navigation -- is enabling the coordination of NASA research with the needs and requirements of FAA Air Traffic Organization (ATO), NextGen (ANG), and Aviation Safety (AVS) organizations.

Question 2b:

How would integrating commercial traffic management and UAM traffic management make air travel safer?

Answer 2b:

Critical elements of aviation safety are situational awareness and separation assurance. A safe National Airspace System must consider all elements, and all aircraft, in order to ensure a truly safe system. The United States' current air traffic management (ATM) system is the safest in the world, but will require coordination and integration with a Unmanned aircraft system Traffic Management (UTM) system in situations where small UAS (sUAS) and urban passenger transport vehicles must interface. NASA and the FAA are currently working the integration of current ATM and future UTM systems through programs such as the FAA's Low Altitude Authorization and Notification Capability (LAANC). The UTM allows for multiple operators to share operational intent with each other through predefined data exchange protocols. Such a "share and care" environment gives complete situational awareness to all sUAS operators so that each sUAS operator can plan, schedule, fly, and track their operation in a safe manner without interfering with other operators. Further, the FAA can add real-time restrictions for safety and security reasons.

The envisioned use cases of both Urban Air Mobility (UAM) and low-altitude sUAS require the vehicles to operate in the same airspace as current manned and commercial aviation. NASA's UTM and Air Traffic Management-Exploration (ATM-X) projects are researching how to enable seamless, safe and efficient integration of all users of the airspace. The federated air traffic management architecture of the UTM project will be leveraged to establish a federated future air transportation management system that is scalable from the current manned daily operations of tens of thousands vehicles, to the envisioned manned and unmanned daily operations of millions of vehicles after the introduction of UAM and low-altitude UAS. NASA seeks to enable equitable access to the airspace for all users, vehicles, and missions by developing and demonstrating a new service-based paradigm leveraging UTM principles using the build-and-test approach to provide:

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LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
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August 22, 2018

Dr. Jaiwon Shin
Associate Administrator
Aeronautics Research Mission Directorate
National Aeronautics and Space Administration
300 E Street, S.W.
Washington, DC 20546

Dear Dr. Shin,

On behalf of the Committee on Science, Space, and Technology, I want to express my appreciation for your participation in the July 24, 2018 hearing titled, "*Urban Air Mobility – Are Flying Cars Ready for Takeoff?*"

I have attached a verbatim transcript of the hearing for your review. The Committee's policy pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee shall be published as a substantially verbatim account of remarks actually made during the proceedings, subject only to technical, grammatical, and typographical corrections authorized by the person making the remarks involved. Individuals whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication.*

Transcript edits, if any, should be submitted no later than **September 5, 2018**. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also enclosing questions submitted for the record by Members of the Committee. These are questions that the Members were unable to pursue during the time allotted at the hearing, but felt were important to address as part of the official record. **All of the enclosed questions must be responded to no later than September 5, 2018.**

All transcript edits and responses to the enclosed questions should be submitted to me and directed to the attention of Sara Ratliff at sara.ratliff@mail.house.gov. If you have any further questions or concerns, please contact Ms. Ratliff at (202) 225-6371.

Thank you again for your testimony.

Sincerely,

Lamar Smith

Lamar Smith
Chairman
Committee on Science, Space, and Technology

cc: Rep. Eddie Bernice Johnson
Ranking Member
Committee on Science, Space, and Technology

Enclosures: Transcript, Member Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Urban Air Mobility – Are Flying Cars Ready for Take-Off?"

Dr. Jaiwon Shin, Associate Administrator, Aeronautics and Research Mission Directorate, NASA

Questions submitted by Chairman Lamar Smith, House Committee on Science, Space, and Technology

1. There are a series of challenges that need to be overcome before UAM can come to fruition. In your opinion, what are the top two most significant technology and regulatory challenges that need to be overcome to make UAM a reality?

2. What roles will be played by the private and public (federal, state, local) sector to advance UAM transportation? How will the various participants in the UAM community collaborate on their roles to address issues as disparate as safety, environment, cybersecurity, zoning etc.?

3. There has been extensive research conducted in battery technology aimed at surface transportation. Are the battery needs of aviation different from surface transportation, and would it be beneficial to consider these issues in research programs?

4. It is a central mission of the National Institute of Standards and Technology (NIST) to develop standards in just about everything. What role has NIST played thus far in the UAM discussion? As the technology progresses and discussions turn to standardizing various aspects of the UAM concept, how might an agency like NIST contribute?

5. Safety concerns relative to VTOLs fall under two general buckets: safety of passengers on the vehicle and safety of the public outside the vehicle in the event of a catastrophe. How might issues of liability be handled when something goes wrong and people perish?

6. As our efforts to develop UAM progresses, where do we expect to see delays – in the development of technology, or in the ability of the public sector (federal, state, local governments) to keep up with innovation by implementing the relevant polices and regulations in a timely manner?

7. Besides NASA and FAA, what other federal agencies have a role to play in the design, development or rollout of VTOLs and the UAM system, and what are their roles?

8. With regard to developing VTOLs and the UAM system, is there any international coordination or collaboration, either with other governments or with companies registered in other nations? How do we walk the fine line between protecting sensitive information or trade secrets, yet still work with foreign counterparts to learn from and teach each other?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Urban Air Mobility – Are Flying Cars Ready for Take-Off?"

Dr. Jaiwon Shin, Associate Administrator, Aeronautics and Research Mission Directorate, NASA

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

1. In his prepared opening statement, Dr. Clarke stated that the four most urgent and most difficult research projects identified by the 2014 National Academies Panel on autonomy are relevant to the realization of UAM. He also stated that while NASA had started research in each of these areas, progress had been slow and needed to be accelerated.

    a. Do you agree with his characterization of NASA's level of activity?

    b. If you agree with the need for increased activity, how and when could NASA begin to accelerate its efforts? If you do not agree, why not?

    c. Would this UAM research require additional funding? If so, when could we expect to see a budget request?

2. Last year, NASA contracted with two consulting firms to conduct a market analysis of UAM to help the agency decide how to deploy resources and develop an appropriate research agenda. Is that analysis complete and if so, to what extent has NASA incorporated those results into its UAM research strategy?

3. In your prepared statement, you state that communities will not accept noise that significantly exceeds background noise levels and that crafting acceptable noise standards will require understanding community response to different noise signatures.

    a. Can you suggest a way by which aircraft noise reduction technology and operational mitigation procedures can be evaluated by communities before UAM operations are initiated?

    b. How can better modeling and simulation tools enhance the ability to predict the noise level from different concepts?

4. Over the last several months this Committee has been examining the state of artificial intelligence and machine learning technologies and their potential benefits for many industries. How will machine learning affect development of UAM? What machine learning and data analysis tools is NASA researching that relate to UAM?

5. According to the FAA, there are approximately 5,000 aircraft in the sky at any time and more than 42,000 flights daily handled by the FAA. I understand that UAM vehicles will be operating at altitudes far below commercial aircraft.

    a. How would integrating commercial traffic management and UAM traffic management make air travel safer?

    b. Can you expand on NASA's research related to detect and avoid and communication requirements for unmanned aircraft systems and its potential applicability to UAM vehicles?

6. NASA's Aeronautics Research Mission Directorate has a critical role in assisting industry in their development of UAM vehicles and operations. NASA provides research results, tools and guidance to its industry partners for safety verification and validation activities. Unique facilities are available to partners under Space Act Agreements. What additional facilities, infrastructure, staff or tools are necessary for NASA to maintain U.S. leadership in UAM research?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Urban Air Mobility – Are Flying Cars Ready for Take-Off?"

Dr. Jaiwon Shin, Associate Administrator, Aeronautics and Research Mission Directorate, NASA

Questions submitted by Representative Jacky Rosen, House Committee on Science, Space, and Technology

1. As the urban air mobility (UAM) industry continues to develop vehicles, it is imperative that we begin addressing safety and management issues. Congress, FAA, NASA, local jurisdictions, and industry will need to work together to answer a multitude of questions, including: who will police the skies or respond to potential accidents? Who will be liable? How will jurisdiction of physical airspace be divided?
    a. Can you address these questions and offer your thoughts as to how we tackle them?
    b. The FAA has "No Drone Zones" throughout the country and over some U.S. military facilities and airports – restricting unmanned aircraft flight. I represent a Congressional District that borders Las Vegas' McCarran International Airport, one of the busiest airports in the country. We are also less than twenty miles from Nellis Air Force Base and just over fifty miles from the Nevada Test and Training Range, which provides the largest air and ground military training space in the contiguous U.S., without interference from commercial aircraft. What will happen if UAM vehicles with passengers fly into this restricted airspace?
2. I know that unmanned aircraft systems traffic management, or UTM, is something NASA has been working on quite extensively.
    a. What can you tell us about the progress or expected results of NASA's research with UTM and UAM?
    b. How would integrating commercial traffic management and UAM traffic management make air travel safer?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-001

December 4, 2018

Reply to Attn of: OLIA/2018-00467:SWQ:dac

The Honorable Ted Cruz
Chairman
Subcommittee on Space, Science
and Competitiveness
Committee on Commerce, Science,
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Ranking Member Nelson, Senators Hassan, Peters and Udall, resulting from the August 1, 2018, hearing, ***"The Search for Life: Utilizing Science to Explore Our Solar System and Make New Discoveries".***

This material completes the information requested during that hearing.

Sincerely,

Rebecca L. Lee

Rebecca L. Lee
Associate Administrator
for Legislative and Intergovernmental Affairs (Acting)

Enclosure

Questions for the Record
Senator Gary Peters

Written Questions Submitted by Hon. Gary Peters to Dr. Thomas Zurbuchen:

Setting Priorities. One of the things Congress did with the 2017 NASA Transition Act was to codify the search for extraterrestrial life as a goal for NASA Science programs.

Question 1: Has codifying this goal helped direct NASA's work and has it changed anything within NASA's science programs?

- If yes, can you please offer examples?
- If no, does Congressional guidance like this need to be more specific, or more forward looking, or something else?

Answer 1: Codifying the goal to search for extraterrestrial life and the supporting steps required, which include understanding the origin and evolution of life, has had a significant impact on NASA's science programs. While NASA has a long history in the search for extraterrestrial life, including advancing priorities expressed in past Decadal Surveys, highlighting the importance of this component of NASA's missions has helped to renew interest in how NASA programs value and prioritize the work that supports this goal. In particular, we have recruited new researchers from other areas of NASA by exploring how their research can contribute and expanded the number of NASA-funded scientists that see their research supporting the search for extraterrestrial life. This has allowed for broader engagement and accessibility of additional NASA programs in answering the key astrobiology questions. The continued emphasis on interdisciplinary and interdivisional research is crucial to the success of NASA's Astrobiology Program and we have seen an increase in non-traditional researchers from other parts of the space and Earth science community proposing to astrobiology solicitations. Lastly, the codification of this goal has provided additional support to our new interdivisional initiatives, such as the Nexus for Exoplanet System Science (NExSS), which is focused on the study and characterization of planets with the greatest potential for signs of life.

Sample Return. The Decadal Survey for Planetary Science covering 2013 to 2023 states the start of a sample return mission from Mars should be the highest priority mission for NASA. Yet we still have no firm commitment to the Mars Sample Return mission in the FY19 budget.

Question 1: When can we expect this commitment be made, or maybe more importantly, when will we need a commitment for sample return missions to maintain leadership in this area?

Answer 1: The President's FY19 budget request includes $50M for studies and technology development towards a potential Mars sample return (MSR) mission. In April 2018, NASA and the European Space Agency (ESA) signed a joint statement of intent to develop a joint MSR plan and to complete the studies needed to reach the level of technical and programmatic maturity required to pursue an effective MSR partnership. NASA will spend the next year developing potential partnership options.

Questions for the Record
Ranking Member Bill Nelson

Written Questions Submitted by Hon. Bill Nelson to Dr. Thomas Zurbuchen:

Question 1: The administration has recommended a new lunar science program in advance of proposed human missions to the moon. I agree that we should do as much science as possible in conjunction in our human exploration programs, but I am concerned about robbing other science programs to pay for it. What is the value of the science that we would get from the administration's proposed science lunar program compared to value of the science we could get if we directed those funds toward competed science missions?

Answer 1: Working with science and human exploration communities, our international partners, and U.S. industry, NASA is refining the goals and objectives for a robust Exploration Campaign. The value of the science we can obtain from such a program is multifaceted and would be conducted in addition to the agency's cadence of competed science missions. One area of focus that is of high interest to both exploration and science is understanding the lunar water cycle and the potential for use of local resources, such as lunar polar water ice. Another area includes the decadal-level science of understanding the Moon's interior via emplacement of a seismic network. There are also several transformative Solar System science questions that can be addressed at the Moon's surface, including establishing the period of giant planet migration and its effects on the Solar System, and providing an absolute chronology for our Solar System.

A substantial benefit to using industry services through the planned Commercial Lunar Payload Services (CLPS) initiative is that it will enable NASA to accelerate a robotic return to the lunar surface. With the recent release of the CLPS Request for Proposals, NASA intends to award multiple contracts for these services through the next decade, with contract missions to the lunar surface expected to begin as early as 2019, and with a company's first delivery no later than December 31, 2021.

Question 2: Given the administration's renewed focus on the moon, I was shocked when NASA announced the cancellation of the Resource Prospector Mission. I understand that NASA is continuing to fund the instruments from Resource Prospector and that at least one company has proposed carrying the instruments on a commercial lunar lander. What are your thoughts on carrying out the investigations originally planned for Resource Prospector under a public-private partnership with a commercial lunar lander company?

Answer 2: Through its planned Exploration Campaign, NASA is returning to the Moon with commercial and international partners in support of Space Policy Directive 1. As part of this effort, the agency seeks to harness the innovation of American space companies to build new lunar landers. NASA has identified a variety of exploration, science, and technology objectives that could be addressed by regularly sending instruments, experiments and other small payloads to the Moon. Some of those payloads will be developed from the agency's Resource Prospector

(RP) mission concept. The agency will ensure that RP data and design activity are captured and considered in shaping this broader effort. Understanding the distribution, quantity, and origin of potential lunar volatile deposits remains a high priority for both SMD and HEOMD.

NASA released the Request for Proposals (RFP) for Commercial Lunar Payload Services (CLPS) to industry on September 6, 2018, which opens the formal competition to further expand efforts to support development and partnership opportunities on the lunar surface. Robotic instruments resulting from RP efforts will be among the early deliveries to the Moon on CLPS missions.

In addition to the RP instruments, NASA will evaluate other instruments as well to fly on the early CLPS missions. A draft Lunar Surface Instruments and Technology Payloads call was released on September 13, 2018. The final call is scheduled to be released by the end of September and will be open to proposals that are near ready to fly on commercial lunar landers and that meet planetary science objectives, human exploration strategic knowledge gaps or technology development objectives.

Question 3: Human and robotic exploration of Mars are complimentary activities, but they are currently managed by different directorates at NASA. In our last hearing, a witness suggested that NASA establish a "Mars Program Office" – a single overarching office to oversee and coordinate all of the robotic missions, technology work and other development activities needed for a human mission to Mars. What are the advantages and disadvantages of this idea?

Answer 3: Given the different lifecycle stages of the current robotic and human Mars exploration efforts, merging the two programs would not offer any clear management advantages at this time. However, this idea may be revisited in the future - once the Agency has obtained additional human spaceflight operational experience at the Moon and further robotic technology demonstrations at Mars, and is in a position to begin adapting these advances to future Mars exploration efforts.

Questions for the Record
Senator Tom Udall

Written Questions Submitted by Hon. Tom Udall to Dr. Thomas Zurbuchen:

Question 1: How does NASA plan to balance the science mission portfolio and continue to remain a global leader in the space industry?

Answer 1: To balance its portfolio of science missions, NASA relies on the advice of the National Academies of Science, Engineering, and Medicine, provided through Decadal Surveys, Mid-Decade Assessments, and ad hoc committee reports. This advice is complemented by more focused, tactical advice from SMD's Divisional Advisory Committees which are chartered under the Federal Advisory Committees Act. Annual performance reviews, such as those mandated by the Government Performance and Results Modernization Act of 2010, are also essential to monitoring NASA's progress on its strategic goals.

Investing in Research Infrastructure and STEM Education. A critical component of the nation's scientific enterprise is the infrastructure that supports researchers in discovery science, and educating the next generation of scientists and engineers.

Question 1: What kind of investments need to be made to ensure that we can continue to advance the innovative frontiers of research and technology that support NASA's science missions?

Answer 1: SMD's technology investments are guided by Agency goals and input from the science community through recommendations set forth in the National Academies' decadal surveys. These goals are designed to produce breakthrough science, which in turn requires significant technological innovation for developing instruments or platforms with capabilities well beyond the state-of-the-art. SMD currently maintains a portfolio of technology development projects to ensure that the right investments are made at the right time to enable the science program.

In Earth Science, the needed scientific measurements for understanding the Earth as a complete system include observations of aerosols, clouds and precipitation, surface mass change, greenhouse gases, atmospheric winds, vegetation, and others. Our program includes investments in lasers, radars, imagers, microwave radiometers, and hyperspectral infrared sounders.

A number of the new instruments developed for Earth Science may also be useful for Planetary Science and Heliophysics, where active and passive remote sensing are important for solar system exploration and to study the source of solar activity and the impact of that activity on the planets and interplanetary space. Because of the broad scope of planetary and lunar missions, investments in both spacecraft and instrument technologies are included in our program. Advanced propulsion systems, electronics, and mechanisms for the extreme environments found from Venus to Europa are major investment areas, as well as instruments for life detection and the characterization of the varied geological, atmospheric, and geophysical properties throughout the solar system.

In Astrophysics, where future missions will address key questions related to the origin of the Universe, how the Universe functions, and whether or not we are alone in the Universe, investments in advanced technology are critically important. SMD's technology programs invest in a wide variety of detectors and mirror coatings for missions spanning the electromagnetic spectrum. Development of star shades and coronagraphs, along with highly stable point systems, are important technologies for exoplanet detection.

In Heliophysics advanced technologies are needed to understand the dynamic solar atmosphere, its effect on the Earth and our solar system, the interactions of the Earth's magnetosphere with the heliosphere, and the physical processes affecting life on Earth. Technology development necessary for future Heliophysics missions includes advanced field and particle detectors, high precision spectropolarimetry, large aperture optics and detectors, along with more highly platforms comprised of large constellations of small spacecraft.

Additionally, investments in information technology are important to enable the accessibility and availability of the voluminous science data products. Advanced information technologies also enable the next generation observing systems, which may consist of constellations of spacecraft, airborne platforms, and numerical models working in a coordinated manner to optimize scientific return.

Question 2: What kind of investments and strategies need to be made to continue to educate the next generation of scientists and engineers so that we can continue to support NASA's science missions?

Answer 2: SMD's strategy is to enable learners of all ages to become leaders in science through access to our unique science content, scientific experts, and our ability to provide authentic and impactful experiences. For investments, SMD directly connects activities with unique science assets to maximize participation and impact. Several examples are: 1) Global Learning and Observations to Benefit the Environment (GLOBE). This program connects Earth systems science in 121 countries; 2) The Robotics Alliance project leverages a strategic partner, FIRST Foundation, to broaden and inspire youth participation; 3) SMD Research Fellowships are directly connected to the science and provide rich opportunities across SMD science disciplines and missions; and 4) SMD's Science Activation program leverages community-based partners throughout the United States, including Rio Rancho Public Library, NM. Finally, alignment with the activities of the restructured NASA Office of STEM Engagement is another mechanism to reach the next generation of scientists and engineers for employment pathways through internship programs.

Questions for the Record
Senator Margaret Wood Hassan

Written Questions Submitted by Hon. Margaret Wood Hassan to Dr. Thomas Zurbuchen:

<u>The Orion Spacecraft and Mars</u>. In 2010, Congress directed NASA to develop new spacecraft for future missions beyond low-earth orbit. Orion, a crew capsule, and the new rocket system, the Space Launch System, were the result of that directive. Given that Mars is widely agreed upon to be a long-term destination for human exploration of space, Orion should be capable of one day carrying astronauts to the Red Planet.

Question 1: How would the Orion spacecraft get to Mars, and what remaining technology is necessary in order for it to make such a trip?

Answer 1: In developing and integrating the Orion crew spacecraft, SLS heavy-lift launch vehicle, and exploration ground-based systems (EGS) to support them, NASA is supporting Space Policy Directive-1:

> *"Lead 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. Beginning with missions beyond low-Earth orbit, 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;"*

Orion, SLS, and EGS are critical elements of NASA's plan for this sustainable program of exploration. These systems will lay the foundation for an infrastructure for human deep space exploration that will support missions to a variety of destinations, including the Moon and Mars. Orion is designed for deep space missions. Deep space exploration systems must navigate a higher risk environment and mission profile than missions in LEO, higher re-entry velocities of returning directly, and higher radiation environments as systems travel through Earth's radiation belts and beyond the protection of Earth's magnetic system.

The Orion spacecraft itself has all the functional capability and on-board storage needed for missions to deep space with a crew of four for up to 21 days, and when combined with additional habitation can support longer duration missions. Orion includes capabilities specifically designed long-duration deep space operations including navigation independent of Earth-orbiting assets, radiation hardening and sheltering for the crew, high-reliability systems with dissimilar redundancy, and avionics that allow for operations by the crew, the ground, on-board automation, or a combination there of. Orion is not by itself, however, designed for carrying astronauts to Mars, which will take hundreds of days to reach using current technologies. Long-duration habitation technologies are needed to support the longer time duration required for such missions. NASA continues to advance habitation systems utilizing ground testing and the ISS including capabilities such as advanced life support systems, logistics reduction, and radiation monitoring and protection. Any decision on whether to use Orion on future Mars missions, which will not be made for several years, will involve balancing Orion's mass and capabilities against alternative approaches.

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

March 7, 2019

Reply to Attn of: OLIA/2018-00550:SWQ

The Honorable Ted Cruz
Chairman
Subcommittee on Aviation and Space
Committee on Commerce, Science,
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Chairman Thune, Ranking Member Nelson, Senators Hassan, Markey, Peters and Udall resulting from the September 26, 2018, hearing entitled, ***"Global Space Race: Ensuring the United States Remains the Leader in Space."***

The questions submitted from Senator Capito remain outstanding at this time. This material will be forwarded to you as soon as possible.

Sincerely,

Suzanne Gillen

Suzanne M. Gillen
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosures

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
"Global Space Race: Ensuring the United States Remains the Leader in Space"
September 26, 2018

Written Questions Submitted by Hon. Gary Peters to Administrator James Bridenstine:

Budget Constraints. During the hearing, Senator Cruz asked why we were able to get to the moon in seven years in the 1960s, whereas now, we are not expected to return to the moon for another twelve years. In your response, you stressed that our current mission is fundamentally different than that of the space race in the 1960s, but also explained that budget constraints on NASA are to blame for the slower pace.

Question 1. In your estimation, can NASA achieve its goal of returning to the moon in twelve years with its current budget?

Answer 1. Yes, the President's FY 2019 budget request sets NASA on a path to return astronauts to the Moon by the end of the 2020s.

Question 2. To what extent would Congress need to increase NASA's budget in order to expedite its return to the moon?

Answer 2. The President's FY 2019 budget request supports a balanced portfolio of human and robotic space exploration and aeronautics research and will enable NASA to address Space Policy Directive-1's call for "[an] innovative and sustainable program of exploration. Beginning with missions beyond low-Earth orbit, 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;"

Question 3. How large of a budget increase would NASA need to match the overall level of productivity that NASA achieved during the space race?

Answer 3. NASA is at one of its most productive points in its history, and this productivity is in part a result of smart design and procurement – not just funding. The Agency is developing and operating technologies and systems for the human exploration of deep space; encouraging the creation of a thriving commercial space economy in LEO and beyond; ensuring robust programs of robotic missions to monitor the Sun and Earth, explore the planets of our solar system, and observe the universe beyond; and supporting continuing advances to make aviation safer, more efficient, and more environmentally friendly.

Additionally, new approaches to commercial partnerships are advancing space activity beyond NASA. For example, using the space launch vehicles developed in partnership with NASA, SpaceX and Northrop Grumman have also helped to bring some of the commercial satellite launch market back to the United States and have reduced commercial launch costs. 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 Laboratory has reached full capacity for allocated crew time and upmass and downmass.

The FY 2019 budget request supports a diversified National Space Exploration Campaign that can be sustained for decades into the future, allowing human presence to be expanded into the solar system.

Question 4. What does the United States stand to lose by delaying our return to the moon?

Answer 4. Our exploration of the Moon will ensure continued U.S. leadership in space, promote the development of commercial services, and inform future missions to Mars. If NASA is to remain a leader we must make the first steps in developing a sustainable approach for human exploration in deep space. If lunar and deep space activities are delayed, we will lose the opportunity to set standards and rules of engagement for this new region in space. Space Policy Directive #1 calls for NASA to "lead an innovative and sustainable program of exploration" as well as "lead the return of humans to the Moon for long-term exploration and utilization". As part of the Campaign, the Agency will begin sending increasingly capable robotic missions to the lunar surface in the next two years. Developed by U.S. commercial companies, these spacecraft will conduct scientific investigations, characterize resources, and provide lunar landing services to customers from America and around the world. Ultimately, these efforts will culminate in the safe landing of U.S. astronauts on the Moon before the end of the 2020s. NASA's drive to conduct robotic and human exploration of the Moon informs the development of technologies needed for future Mars missions. The Moon will also serve as a stepping-stone, a training ground, and a platform to strengthen commercial and international partnerships and prepare for future human missions to Mars and other destinations.

Protecting Astronauts from Radiation. During the hearing, you testified that NASA is committed to sending humans to the moon and to Mars and to developing cis-lunar space. In these pursuits, United States astronauts will be removed from the Earth's protective magnetic field and will be exposed to harmful levels of radiation. Additionally, these missions will expose them to potential extreme space weather events, such as a coronal mass ejections, and other hazards.

Question 1. What is NASA doing to protect astronauts from radiation on these missions?

Answer 1. NASA's Human Research Program (HRP) investigates and mitigates the highest risks to human health and performance, providing essential countermeasures and technologies for human space exploration. The HRP Space Radiation Element is focused on quantifying and mitigating radiation health risks from a biological perspective and funds ground-based research at the National Space Radiation Laboratory (NSRL). Research is aimed at understanding and mitigating the effects of space radiation on biological systems for the major risks of cancer, degenerative tissue (cardiovascular) diseases, and acute and late central nervous system effects.

Mitigation efforts are focused on accurate risk quantification, individual sensitivity, identification of biomarkers, and development of biological countermeasures. Research results are incorporated into risk models used to assess exposure limits and to derive design requirements. HRP also sponsors studies on the role of genetic, epigenetic factors, and biomarkers on individual susceptibility to radiation induced diseases, which can inform future individualized risk assessments.

In deep space, astronauts will be exposed to different types of radiation which may call for different mitigation approaches. Solar Particle Events, involving protons emitted from the sun, can be mitigated using shielding, and NASA has made significant investments in shielding research and technology development. Shielding concepts and prototypes and space weather warning capabilities being developed will inform the development of deep-space exploration vehicles and mission operations. In contrast, Galactic Cosmic Radiation (GCR), which includes high-charge, high-energy ions (together with secondary radiation produced from GCR interactions with spacecraft materials or human tissue), cannot be mitigated with current shielding technology. The primary focus of the NASA space radiation health research is on understanding the health risks associated with exposure to GCRs and developing biological countermeasures to mitigate these risks. Using the NSRL, developed in collaboration with Brookhaven National Laboratory, NASA is able to undertake biological research studies to better understand and develop mitigation strategies to ensure the astronaut health and performance during long-duration deep space missions.

As research matures, greater emphasis will be placed on the identification of countermeasures tailored to provide risk reduction for crewmembers. Additionally, NASA is making technical investments through STMD and AES in areas to protect crew from radiation exposure. These include improved risk assessment modeling, radiation prediction, space weather models and forecasting, and radiation protection systems, such as thick materials and hybrid shielding designs. Operational strategies, including miniaturized radiation measurement technologies for future human exploration missions, solar particle event shelter concepts, and a water wall concept for shielding the crew quarters are also being pursued.

Question 2. How will NASA protect astronauts, both in deep space and in low earth orbit, from an extreme space weather event?

Answer 2. Astronauts in LEO are significantly shielded from solar energetic particle (SEP) events by the protective influence of the Earth's magnetic field Van Allen radiation belts and the shielding of the ISS. For deep space missions, NASA has developed the capability to design, analyze, and optimize spacecraft shielding to minimize astronaut exposure to space weather events. Since SEPs are of short-duration and high intensity, SEP radiation can be quite manageable with optimized shielding and miniaturized *in situ* radiation monitoring and warning system on the spacecraft to alert crew to seek protection in a storm shelter within the spacecraft. Additionally, NASA is currently undertaking a space weather technical assessment through its NASA Engineering and Safety Center (NESC) to understand the space weather assets and analysis tools required to improve modeling during dynamic space weather conditions and allow high-accuracy forecasting to enhance mission operational flexibility and planning, especially for lunar surface EVAs.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
"Global Space Race: Ensuring the United States Remains the Leader in Space"
September 26, 2018

Written Questions Submitted by Hon. Edward J. Markey to Administrator James Bridenstine

Question 1: A consortium of non-profit foundations and organizations recently announced a $4B initiative to harness technologies to enhance sustainability and mitigate the effects of climate change. How can NASA work with non-profits and commercial companies to coordinate research on climate change in areas such as hazardous weather events, food security and agriculture, and ocean health?

Answer 1: One of the ways NASA forms working partnerships with both non-profit and commercial organizations to further research into areas such as hazardous weather events, food security and agriculture, and ocean health is through the formation of research groups such as NASA Harvest, the NASA Water Resources Program, and the NASA-USAID SERVIR Program. NASA Harvest is an Applied Research consortium comprised of non-profit, private sector, and government organizations that targets global food security and agriculture challenges with Earth Observations. NASA's Water Resources Program and the Western Water Application Office (WWAO) is a key partner for leveraging NASA's significant observation and science accomplishments in terrestrial hydrology to help address the pressing issues of freshwater impacts on, and from, agriculture. SERVIR partners with non-profit organizations to improve understanding of, and reach to, local users in developing countries. SERVIR also partners with commercial organizations to provide data services needed for applications addressing hazardous weather events, food security and agriculture.

NASA also offers funding for research through the NASA Research Opportunities in Space and Earth Sciences (ROSES) program, an omnibus solicitation with many individual topics, including the Weather Focus Area, the Disasters program, and the Modeling, Analysis and Prediction program. Additionally, NASA contributes to external Earth science efforts through a large repository of Earth-observation data from a fleet of Earth observation satellites and ground based instruments. Through the Earth Observing System Data and Information System (EOSDIS) and NASA Center for Climate Simulations (NCCS), this data is being made more readily available to researchers and applications users in government, academia, private sector, and non-profit sector. These data products have been used research into areas of extreme weather events, food security, agriculture, and ocean health in the changing climate.

Question 2: The planetary science community made Mars Sample Return its highest-priority large initiative in the last decadal survey, but progress on achieving returned samples has been relatively slow, due to the perceived cost of such a landed mission or series of missions. What steps is NASA taking to realize the goal of returned Martian samples?

Answer 2: The President's FY19 budget request includes $50M for studies and technology development towards a potential Mars Sample Return (MSR) mission. The Mars 2020 rover, set to launch in 2020, enables the first steps for MSR. This mission will identify and characterize samples, as well as set aside a cache of samples for potential retrieval in the future.

Additionally, NASA is working with the European Space Agency (ESA) on a joint approach to this significant undertaking of MSR. In April 2018, NASA and ESA signed a Statement of Intent (SOI) to develop a joint MSR plan and to complete the studies needed to reach the level of technical and programmatic maturity required to pursue an effective MSR partnership. Moreover, NASA will spend the next year studying other potential partnership options that will leverage international participants as well as increase commercial capabilities.

Question 3: The NASA Engineering & Safety Center (NESC) recently released a report about the potential hazards of Martian dust to human explorers and even robotic missions. How is NASA working to preempt and address some of the scientific and safety issues that Martian dust poses to mission success?

Answer 3: In order to better understand Martian dust and the issues it may pose to mission success, the Mars 2020 rover carries a science instrument that will help us better understand dust properties and activities on the surface of Mars. The Mars Environmental Dynamics Analyzer (MEDA) investigation will monitor the weather and dust environment at the landing site, characterize dust particle size and distribution, and improve our overall understanding of atmospheric dynamics that affect dust transport. These measurements will shed new light on the dust lifting processes that lead to regional dust storms and dust devils. In addition, they will help us understand geological processes actively shaping the Martian surface today. MEDA's measurements will also help mission operators understand the dust load entering the gas inlet by another payload on the Mars 2020 rover, the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), which will inform the design of oxygen generation systems for future human exploration.

Additionally, the President's FY19 budget request includes $50M for research and development advancing a potential MSR mission. If funded, this will be another step towards returning samples from Mars that will include Martian dust, thus allowing us to further assess potential hazards it may pose. The Mars 2020 rover is equipped to collect samples of Martian rock and soil, which will include dust that would be stored on the Martian surface for eventual return to Earth by a future mission. If returned, the dust could be analyzed in laboratories with sophisticated equipment that would greatly increase our understanding of its physical and chemical properties and potential hazards it may pose.

Question 4. When external factors or scientific discoveries prompt a reassessment of decadal survey priorities, how can NASA work with the National Academies of Sciences, Engineering, and Medicine to allow and vet input from the scientific community on potential changes?

Answer 4: *Ad hoc* committees of the Space Studies Board (SSB) of the National Academies of Sciences, Engineering, and Medicine (NASEM) provide input to NASA on research priorities through decadal surveys in each of the areas focused on by SMD's research divisions: Planetary

Science, Earth Science, Astrophysics and Heliophysics. Additionally, other *ad hoc* committees of the SSB conduct midterm assessments of NASA's progress on decadal survey goals five years following each decadal survey. Between Decadal Surveys and Mid-Term Assessments, Discipline Committees of the SSB exist to allow and vet input from the scientific community when external factors change or when scientific discoveries occur. Combined, these assessments review the responses of NASA's efforts to the decadal surveys and help NASA to remain agile and responsive to the needs of the scientific community while keeping faith with Decadal Survey goals.

Question 5. Is NASA planning on adopting sexual misconduct reporting guidelines for its awardees that mirror the National Science Foundation guidelines, including a requirement that grantees receiving funding from NASA submit to the agency any findings or determinations of sexual harassment and/or misconduct? If not, why not?

Answer 5. NASA is planning on adopting sexual misconduct reporting guidelines for its awardees that mirror the National Science Foundation guidelines, including a requirement that grantees receiving funding from NASA submit to the Agency any findings or determinations of sexual harassment and/or misconduct. NASA's new grant terms and conditions will allow the Agency to learn about both discrimination and harassment investigations and findings in real time, including the names of NASA Principal Investigators (PIs) and Co-PIs either placed on administrative leave pending investigation or against whom a finding of discrimination or harassment has been made. This will enable the Agency to take action to address the situation, for example, substituting a new PI or co-PI on the grant. We anticipate issuing a Federal Register notice to effectuate the change to our grant terms and conditions in the February to April timeframe of 2019.

In addition, NASA's Administrator recently issued a policy statement reaffirming the Agency's commitment to anti-discrimination and anti-harassment among the Agency's grantee institutions. The statement is accessible at:
https://missionstem.nasa.gov/docs/Bridenstine_Title_IX_Policy_Statement_TAGGED.pdf. NASA also is currently working on enhancements to the Agency's Civil Rights Assurance Form to address the need for education and awareness on the part of top grantee officials regarding civil rights requirements, and to receive accurate information on their institutions' civil rights postures, including cases of discrimination and harassment. The process is expected to take approximately six to eight months; therefore, we hope to have the new form in place by the close of FY 2019.

Question 6. How is NASA working to improve its policies, procedures, and practices surrounding the travel approval process for Center employees to attend scientific and professional conferences, meetings, and workshops, in order to ensure that the current approval process does not cause undue delay and uncertainty when developing travel arrangements?

Answer 6. NASA continues to evaluate its current conference processes and procedures to identify areas to improve efficiency. One of the more recent changes includes the modification to allow attendees of non NASA-sponsored conferences costing the agency less than $90K in total expenses to receive automatic approval to attend events circumventing the formal approval process. As of June 2018, the 6 tier approval process has been condensed to a 3 tier approval process. Final approval rests with the DCFO for conferences $100K and above.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
"Global Space Race: Ensuring the United States Remains the Leader in Space"
September 26, 2018

Written Questions Submitted by Hon. Margaret Wood Hassan to Administrator James Bridenstine:

Question 1. As the discussion around ensuring American leadership in the space race continues, I'd like to ask you about one of the projects NASA is developing known as the Space Launch System. Designed to support deep space missions, the Space Launch System project was originally scheduled to have its first test launch last year, but that test was delayed and now is scheduled for the end of 2019. The Space Launch System project seems very promising, and it is a prime example of American ingenuity and engineering expertise. Some very talented people at companies in my own state of New Hampshire are part of this project. What will you to do make sure that the Space Launch System meets the December 2019 test launch goal?

Answer 1. NASA is holding exploration systems development programs and contractors to a fall 2020 launch for Exploration Mission-1 (EM-1) with several months of schedule risk associated with first-time production, integrated test, and integrated operations.

Recent issues (primarily due to delays in the shipment of the European Service Module from Bremen, Germany to Kennedy Space Center from July 2018 to November 2018, and impacts to the Space Launch System [SLS] schedule due to first-time production issues such as tube contamination and work flow around complex elements like the cores stage engine section at the Michoud Assembly Facility) have consumed six to eight months of EM-1 schedule margin. All other exploration elements (including the Orion Crew Module and Launch Abort System production; SLS engines, boosters and stage adaptors; and Exploration Ground Systems (EGS) construction on the Mobile Launcher, launch pad, and Vehicle Assembly Building) are on track.

About 30 companies in New Hampshire are supporting the development of the SLS heavy-lift rocket, the Orion crew vehicle, and EGS.

STEM Education and Outreach. At a recent hearing, I had the opportunity to ask Dr. Kelvin Droegemeier, the nominee for Director of the White House Office of Science and Technology Policy, about science, technology, engineering, and mathematics (STEM) education in the United States. The United States is not producing enough qualified STEM graduates to meet our needs. This is a well-known fact, and part of the problem is that women and people of color are not joining these fields at equitable rates – leaving behind a large portion of our talent and impacting our future workforce pipeline. I asked Dr. Droegemeier about how the Office of Science and Technology Policy would meet those challenges, and he gave me a thoughtful answer. But I'm also interested in how NASA is approaching this problem, especially given that the President has proposed eliminating NASA's Office of Education.

Question 1. What have you done to encourage STEM education in the face of an Administration that does not seem to treat that as a priority?

Answer 1. NASA's new common vision, mission and focus areas drive Agency endeavors in STEM engagement and public engagement. Under the leadership of the Office of STEM Engagement and Agency STEM Engagement Council, in partnership with the Mission Directorates and Centers, NASA is focusing on creating unique opportunities for students and the public to contribute to NASA's work in exploration and discovery; building a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content and facilities; and strengthening public understanding by enabling powerful connections to NASA's mission and work. Additionally, NASA is engaged in interagency efforts to support the Administration's five-year strategic plan for STEM education, which outlines a vision in which all Americans have lifelong access to STEM education and the United States will be a global leader in STEM literacy, innovation, and employment.

In 2018 NASA executed a full portfolio of STEM engagement activities through established programs (Space Grant, MUREP, EPSCOR, etc.), mission-related events, educational experiences, scholarships and internships, mentoring and tutoring and educational materials put into the hands of countless students and teachers. This work was accomplished through a partnership between the NASA field centers, Headquarters and the Mission Directorates. In FY17 NASA STEM engagement efforts served 2672 institutions and 842,097 students while also providing 5921 significant awards. The final numbers for FY18 are still being tallied, but they will be of the same general magnitude.

Question 2. Should Dr. Droegemeier be confirmed, will you commit to working with the Office of Science and Technology Policy to build our STEM workforce and improve outreach to women and people of color?

Answer 2. NASA does commit to continue its significant work to build the STEM workforce in general, and particularly in the area of underrepresented populations, both as an individual agency and in connection with many other federal entities. As part of the Federal STEM Education 5-year Strategic Plan and as Co-STEM & FC-STEM co-chair(s), NASA will help coordinate federal STEM education strategy and investment. Currently, this interagency group will provide the framework for individual agency and collaborative efforts to ensure the nation builds the STEM workforce that it needs.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
"Global Space Race: Ensuring the United States Remains the Leader in Space"
September 26, 2018

Written Questions Submitted by Hon. Bill Nelson to Administrator James Bridenstine:

Question 1. NASA's inspector general confirmed at a recent committee hearing that it's unlikely NASA will save much, if any, money if the agency transitions the International Space Station (ISS) to a commercial operator. Given the ongoing cost of research and transportation, the near-term contributions proposed by the administration to help fund development of commercial platforms and the enormous cost of disassembling and deorbiting the ISS, it appears that ending government funding for the ISS in 2024 as the administration has proposed could be the most expensive possible option. How much money does NASA actually plan to free up under the administration's plan and when would we see any savings?

Answer 1. NASA's vision for low-Earth orbit (LEO) is a sustained U.S. commercial LEO human spaceflight marketplace where NASA is one of many customers. 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. 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 that are inherently governmental, maximizing its resources toward missions beyond LEO, while still having the ability to utilize LEO for its ongoing needs.

In an ongoing effort to foster commercial activity in space, NASA has selected companies to study the future of commercial human spaceflight in LEO, including long-range opportunities for the International Space Station (ISS); twelve companies are providing studies.

The studies will assess the potential growth of a LEO economy and how to best stimulate private demand for commercial human spaceflight. The portfolio of selected studies will include specific industry concepts detailing business plans and viability for habitable platforms, whether using the space station or separate free-flying structures. The studies also will provide NASA with recommendations on the role of Government and evolution of the space station in the process of transitioning U.S. human spaceflight activities in LEO to non-Governmental enterprises. The final study reports will be delivered to NASA in December 2018, after which NASA will be better informed as to which options best enable the vision and realize potential cost savings.

Human Exploration Plan. NASA recently delivered the Human Exploration Roadmap. The plan, delivered nine months later than required by the NASA Transition Reauthorization Act of

2017, is lacking in any new details, including those on how proposed lunar missions will advance the ultimate goal of missions to Mars. In fact, the report calls for a human lunar landing by 2029 and only mentions in passing the expectation of a landing on Mars sometime beyond the 2030s.

Question 1. What does NASA need to get to Mars in the 2030s?

Answer 1. In December of 2017, President Donald J. Trump signed Space Policy Directive-1 (SPD-1). The President directed the NASA Administrator:

> *"to lead 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. Beginning with missions beyond low-Earth orbit, 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 Agency anticipates an eventual series of crewed Mars missions culminating in a surface landing. NASA will advance robotic access to Mars in preparation for human exploration, and an innovative robotic Mars round-trip sample return will tie directly into these efforts.

Human exploration requires a long term, sustained effort. NASA is building capabilities to create a resilient architecture featuring multi-use evolvable space infrastructure. This minimizes unique developments, with each mission leaving something behind to support subsequent missions. NASA is developing the capabilities required for deep space exploration on a schedule consistent with the available resources and the Agency will continue to revise its plans as it learns from the experience it will gain by accomplishing the milestones we establish in the plan.

NASA's drive to conduct robotic and human exploration of the Moon informs the development of technologies needed for future Mars missions. In the 2020s, the development and deployment of the Gateway to cislunar space will also serve as a stepping-stone, a training ground, and a platform to strengthen commercial and international partnerships and prepare for future human missions to Mars and other destinations.

Question 2. We can't afford to sacrifice NASA's other critical priorities in science in technology, but given the budget increases the agency has gotten in the past couple years, what can NASA do to speed up human exploration plans?

Answer 2. The President's FY 2019 budget request supports a balanced portfolio of human and robotic space exploration and aeronautics research and will enable NASA to address Space Policy Directive-1's call to:

> *"Lead 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. Beginning with missions beyond low-Earth orbit, 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 budget request supports a diversified, well-paced National Space Exploration Campaign that can be sustained for decades into the future, allowing human presence to be expanded into the solar system. One of the key ways in which this is being pursued is by identifying and using more innovative procurement, design, and architecture approaches that incentivize greater efficiency in the development process, lowers the magnitude of cost and schedule overruns, and create more resilient strategies with multiple options for achieving objectives in case key systems face challenges.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
"Global Space Race: Ensuring the United States Remains the Leader in Space"
September 26, 2018

Written Questions Submitted by Hon. Tom Udall to Administrator James Bridenstine:

Climate Change. In early October, the Intergovernmental Panel on Climate Change released a shocking and concerning report revealing that both human society and our planet will experience the serious consequences of climate change as soon as 2040—in just 12 short years.

Question 1. What is your interpretation of the current IPCC Report on "Global Warming of 1.5 degrees C", and the call for an all hands on deck approach to address climate change?

Answer 1. NASA scientific data and observations are used by the research community to provide valuable and executable scientific knowledge. Such knowledge is documented in peer-reviewed literature and is made routinely and widely available to scientists, policymakers, industry, and citizens throughout the Nation and the world. The recent IPCC report "Global Warming of 1.5 degrees C" includes sustained observations gathered by NASA, together with its partners. It is then the purview of policymakers to find needed solutions.

Question 2. What is NASA's role in helping the US reduce the dangerous impacts of climate change?

Answer 2. NASA is committed to providing data and research that allows policymakers to make decisions on behalf of the American public. NASA's role is not to refute arguments or reduce dangerous impacts of climate change – our role is to observe, monitor, and understand the Earth and its environment, and to produce objective data. NASA does this independently and through engagement with assessment processes, including – but not limited to – those of the U.S. Global Change Research Program (for example, volume 1 of the National Climate Assessment – aka "Climate Science Special Report" released 11/3/17). NASA also conducts work utilized by Intergovernmental Panel on Climate Change (IPCC) periodic assessments and special reports.

NASA satellite and related surface measurements show clearly that there are decadal-scale trends that are observable from space, including near-monotonic increases in global-average sea-level over the past 25 years, decreases in both the extent and thickness of Arctic sea ice, increases in annual-average atmospheric levels of CO_2 and other radiatively-active greenhouse gases, and general decreases in the rate of expansion of the Antarctic stratospheric ozone hole area. Forty-five years of Landsat data show significant regional land use/land cover changes, and decreases in the size of land glaciers globally. GRACE gravity measurements, combined with Operation IceBridge and non-NASA satellite measurements (CryoSat-2), and extensive harmonizing research analyses (from the Ice sheet Mass Balance Inter-comparison Exercise or IMBIE-1 and -2 activities, joint with the European Space Agency) document and quantify trends in land ice sheet mass in Antarctica and Greenland.

Question 3. How would you address the arguments of outside entities – and those serving in the current Administration – who refute scientific research on climate change, including NASA's own research findings?

Answer 3. NASA is committed to providing data and research that allows policymakers to make decisions on behalf of the American public. NASA's role is not to refute arguments – it is to observe, monitor, and understand the Earth and its environment, and to produce objective data. NASA does this independently as an agency and through engagement with assessment processes, including – but not limited to – those of the U.S. Global Change Research Program (for example, volume 1 of the National Climate Assessment released in November 2017). NASA also conducts work utilized by Intergovernmental Panel on Climate Change (IPCC) periodic assessments and special reports.

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Severe Weather Forecasting. You have previously stated that: spending 30 times as much money on global warming research as on weather forecasting and warning is a gross misallocation of funds.

Question 1. In your opinion, do you believe that more funding is needed to improve the technologies required for severe weather forecasts?

Answer 1. No. NASA is investing appropriately in technologies needed to forecast severe weather events.

Question 2. What role does climate change research play in advancing our ability to better prepare for severe weather in the future?

Answer 2. A significant amount of current climate change research is focused on the question of how weather, including severe weather, might change in the future. This research includes investigation of potential changes in the frequency and severity of heat waves, cold spells, hurricanes, extratropical cyclones, and episodes of severe precipitation from weather events known as atmospheric rivers. A better understanding of how such processes might change in the future will directly advance our ability to prepare for severe weather in the future. Climate change research also involves the study of many processes that are critical not only for understanding climate, but for weather as well. An example would be processes such as cloud microphysics and aerosol-cloud interactions that are critical to understanding the formation of precipitation. Improvements in both our understanding of these processes and our ability to represent them in climate models would also improve their representation in weather models, as weather and climate models are very similar. This will lead to improved capabilities for weather forecasting, and will ensure that we will have improved forecasting tools to enable better forecasting of future severe weather events. Investing in advanced technologies could help improve weather forecasting and provide weather data at a lower cost. An example of this is the development of CubeSat-based weather observation platforms, arrays of which would allow for higher spatial and temporal accuracy of storm evolution, which would in turn allow for the refinement of severe weather modeling.

NASA Workforce and Activities in New Mexico. I am interested in working with you to support NASA's workforce and activities in New Mexico. NASA has a presence at White Sands Missile Range and we want to increase activity at that site. Many commercial companies are preparing to offer spaceflight services not only for tourism, but also for science and technology development. New Mexico's Spaceport America is one of the best places for this kind of activity.

Question 1. How do you see these platforms, many of which have already manifested payloads, fitting into NASA's overall mission? And, could these vehicles offer a viable opportunity to expand the agency's science and human spaceflight opportunities?

Answer 1. NASA intends to continue to contract with U.S. suborbital reusable launch providers for the rapid and affordable testing of technologies intended for use in space. NASA does not currently have an identified need for human suborbital flights, however, suborbital flights do present an opportunity to test technologies for use in human exploration missions.

Question 2. What is NASA's position on vertical launch and point-to-point launch?

Answer 2. NASA encourages innovative approaches in the commercial space sector and does not express a preference for a particular technical solution provided the launch vehicle meets the requirements of mission.

Private Space Companies. In light of private investors, like SpaceX, Blue Origin, Virgin Galactic, and Virgin Orbit investing in space technologies and pushing for space exploration:

Question 1. Where do you see NASA's role in space exploration?

Answer 1. NASA's role in space exploration is laid out in the National Space Exploration Campaign report, submitted to Congress in September 2018; the report can be accessed at the link below:

https://www.nasa.gov/sites/default/files/atoms/files/nationalspaceexplorationcampaign.pdf

As part of the Campaign, NASA will leverage partnerships with the rapidly advancing commercial sector and international community to lay the foundation for a future of unlimited opportunity, discovery and growth.

Question 2. Will commercial suborbital human flights either benefit or conflict with NASA's work? Does NASA have plans to leverage the work of these private companies in human space exploration?

Answer 2. NASA seeks to accelerate the pace of human exploration by both fostering and harnessing the growth of the U.S. commercial spaceflight industry. While NASA itself does not currently have an identified need for human suborbital flights, NASA has contracted with Virgin Galactic, Blue Origin, and others to use suborbital reusable launch vehicles as rapid and affordable testbeds for the testing of technology intended for use in space. As one of multiple customers, NASA anticipates continuing to use these commercial services for space exploration technology demonstration outside of the flight providers' other applications for the vehicles. Support from NASA as a customer, and through cooperative agreements or public-private partnerships with industry, helps feed the development of U.S. commercial spaceflight capabilities. Likewise, the growth of the U.S. commercial spaceflight industry drives innovation, helps reduce cost and increase the speed of future NASA missions.

Question 3. Does NASA have current plans to get back into the business of human space exploration? Is there a desire to travel to Mars, and what do those research goals entail?

Answer 3. Please see response to Question #1, above. The National Space Exploration Campaign report discusses NASA's current plans related to human Mars missions.

2017 NASA Authorization. Congress passed the last NASA Authorization in 2017. This law continues to guide NASA as a multi-mission agency with a, "balanced and robust set of core missions in space science, space technology, aeronautics, human space flight and exploration, and education."

Question 1. What specific strategies are you going to use to execute NASA's multiple missions, which encompass not just human space flight but also initiatives such as space-based observations of the Earth?

Answer 1. For NASA's science activities, we rely on the National Academies of Sciences, Engineering, and Medicine (NASEM) to provide input on the scientific community's priorities for each of the four major science areas within Earth and space science. *Ad hoc* committees of the Space Studies Board (SSB) of NASEM provide input to NASA on research priorities through decadal surveys in each of the areas focused on by SMD's research divisions: Planetary Science, Earth Science, Astrophysics and Heliophysics. Additionally, other *ad hoc* committees of the SSB conduct midterm assessments of NASA's progress on decadal survey goals five years following each decadal survey. Between Decadal Surveys and Mid-Term Assessments, Discipline Committees of the SSB exist to allow and vet input from the scientific community when external factors change or when scientific discoveries occur. Combined, these assessments review the responses of NASA's efforts to the decadal surveys and help NASA to remain agile and responsive to the needs of the scientific community while keeping faith with Decadal Survey goals.

NASA Technology and Safety Regulations. In light of the recent booster malfunction during the launch of the Soyuz MS-10 space craft set for the International Space Station:

Question 1. What is your confidence in joint space programs?

Answer 1. The International Space Station (ISS) is helping to cement continuing U.S. leadership in human spaceflight, with over 18 years of humans living off the planet, and Station is a clear demonstration of the benefits to humankind that can be achieved through peaceful global cooperation. Through the encouragement of a LEO economy, NASA is supporting the development of competitive American industrial capabilities and markets. The ISS partnership, with America as its leader, is very important; leadership in space brings with it economic growth, technological prowess, and national pride, and contributes to American global leadership more broadly.

The Soyuz launch vehicle has a tremendous safety track record. After the October 2018 Soyuz MS-10 launch anomaly, Roscosmos provided the ISS partnership with insight into the anomaly investigation and mitigation process. Through close consultation and collaboration, NASA and its international partners were able to successfully resume launching crew to the ISS and avoid significant impacts to this critical program.

Question 2. The DOD is making a concerted effort to replace the RD-180 engine in space launch. Does NASA have plans to do the same? If so, what are the options NASA is exploring?

Answer 2. In general, with respect to commercial cargo and crew support to the International Space Station (ISS), as well as launch services for NASA and other civil-sector satellites, NASA procures launch services from commercial providers. NASA expects its commercial providers meet their contractual commitments with launch solutions that are consistent with national policy.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
"Global Space Race: Ensuring the United States Remains the Leader in Space"
September 26, 2018

Written Questions Submitted by the Hon. John Thune to Hon. Jim Bridenstine

Question 1. What specific steps is NASA taking in partnership with other federal agencies to improve space cybersecurity within the agency's domain as called for in the National Cyber Strategy issued September 2018?

Answer 1. NASA supports the National Cyber Strategy to protect National space assets and support infrastructure from evolving cyber threats by working with other federal Agencies to strengthen the cyber resilience of existing and future space systems. These efforts include strategic leadership engagement, such as NASA's participation in the National Security Council's (NSC) Space Cybersecurity Working Group. Through this group, NASA actively collaborates with other Agencies and provides input to the National Space Cybersecurity Implementation Plan.

NASA serves as the leader of the 'Cyber Resiliency of Space Systems' goal for the National Space Science and Technology Partnership Forum. In 2015, this interagency forum was established by the USAF Space Command Chief Scientist and the NASA Chief Technologist to identify synergistic efforts and technologies between multiple government organizations with space equities, explore ways to collaborate on investments, and facilitate cross-agency engagement. The Forum has 18 Federal agencies participating and sharing best practices and standards for space cybersecurity. The cyber goal is to strengthen space system cybersecurity across the U.S. Government through activities including cybersecurity analysis and metrics, red teaming, work with cyber test ranges, and government-commercial information sharing. The fourth Technical Exchange Meeting is scheduled at Buckley Air Force Base, Colorado, in March 2019.

NASA collaborates daily with other Federal agencies through its normal processes and agreements as it works to build and operate spacecraft and execute NASA missions. Many of NASA's missions (e.g., Landsat 9) are developed through partnerships with other Federal agencies, and require constant inter-Agency cybersecurity cooperation to ensure the safe, secure and successful achievement of mission objectives.

Question 2. The NASA Office of Inspector General in May 2018 identified that the acquisition of certain IT products from a Chinese technology company was conducted without a supply chain risk assessment and potentially violated the Anti-Deficiency Act (ADA). What is the current state of NASA's review into whether such acquisition violated the ADA? If NASA has determined it did not violate the ADA, why not?

Answer 2. NASA Office of the Chief Financial Officer (OCFO) concluded its preliminary review of potential Anti-Deficiency Act (ADA) violations for all seven transactions referenced in Recommendation Number 5 of NASA Office of Inspector General (OIG) Audit Report IG-18-019. The OCFO's final Preliminary Review report, issued on September 27, 2018, concluded that no Anti-Deficiency Act violations occurred. The NASA Office of General Counsel (OGC) reviewed and concurred with OCFO's report.

Because the OIG Audit report focused on the NASA Office of the Chief Information Officer (NASA OCIO) Risk Assessment process and cyber-security concerns, the OCFO worked closely with the NASA OCIO in analyzing each of the transactions cited by the OIG that were the focus of potential ADA violations. OCIO and OCFO researched each transaction, obtained and reviewed both technical, procurement, and other Risk Assessment database information, and had OCIO contact the FBI when required. OCIO and OCFO executed all protocols/risk assessments and other analysis required pursuant to OCIO and OCFO policies. This technical information was vital to the determination of whether or not a potential ADA violation occurred because the OIG Audit Report based its conclusions of such potential violations on the absence of "undergoing the required supply chain risk review and approval process."

Of specific concern was the noted purchase of one item, an IT product from a Chinese technology company. Further, the report indicated this purchase violated the "intent" of the 2013 law and, according to the OIG, constituted an ADA violation.

During the Preliminary Review, OCFO found that the purchase of concern to the OIG, the one IT product from a Chinese technology company, occurred after FY2013. OCFO consulted with NASA's OGC, which advised OCFO that the 2013 law was not applicable and instead, the later and narrower appropriations restrictions applied. Accordingly, only high- and moderate- risk systems were required to undergo the required supply chain risk review and approval process.

As such, OCFO determined the IT product from the Chinese technology company was part of a NASA moderate-impact system, but the required risk assessment was conducted for this purchase back in 2016. The requisite RFI (Request for Investigation) dated June 15, 2016, was approved in July 2016. Additionally, because of the expressed concerns of OIG regarding potential involvement of Chinese companies, OCIO conducted additional research and reconfirmed in August 2018 that this particular item was manufactured in the United States. As such, the purchase of the IT product from the Chinese technology company complied with both the narrower appropriations restrictions and the necessary OCIO Risk Assessment and acquisition protocols. Thus, OCFO concluded there was no ADA violation related to the IT product from the Chinese technology company.

Finally, OCFO's Preliminary Review concluded the criteria cited by the Auditors for a required Risk Assessment did not apply for the other six IT and communication transactions cited in the OIG report. These purchases questioned by the OIG were not made or incorporated into a "high-impact" or "moderate-impact" system as defined by Federal Information Processing Standards Publication 199, and pursuant to Public Law No. 113-6 and subsequent appropriations, a risk assessment was not a requirement for these purchases. OCFO and OCIO also confirmed the IT assets were either not connected to the NASA system and/or purchased solely for use in Low-Risk systems. Thus, no ADA violations occurred related to these transactions.

Question 3. In 2016, the Government Accountability Office (GAO) called for NASA to improve its security over high-impact systems – systems that could have a severe or catastrophic effect if compromised. GAO deemed these recommendations to be "priority" recommendations for the agency, yet some of the recommendations still have not been implemented by NASA. At the direction of Congress, GAO followed up with a broader looked at cybersecurity weaknesses with a report entitled "Urgent Action Needed to Address Significant Management and Cybersecurity Weaknesses." Is the agency working in an urgent manner to address these cybersecurity concerns?

Answer 3. NASA is working diligently to address cybersecurity concerns identified in the GAO's audits on improving security for high-impact systems (GAO-16-501) and taking deliberate actions to address significant management and cybersecurity weaknesses (GAO-18-337). In addition to addressing the recommendations of this report, NASA recently achieved its first "Managing Risk" rating on the OMB Cybersecurity Risk Management Assessment based on the Agency's FY2018 Federal Information Security Management Act (FISMA) metrics. Key metrics improvements include credentialing and authorization protecting user accounts using PIV cards and intrusion detection and prevention capabilities, achieving 99.8 percent on DHS BOD 18-01.

For GAO-16-501, NASA successfully completed the requirements to close three of five recommendations, as of September 2018. NASA is working to close the remaining two recommendations, which are nearly complete. These two recommendations pertain to: (1) updating security assessment plans to ensure that controls are comprehensively tested; and, (2) updating NASA's continuous monitoring strategy to include performance metrics. Both of NASA's selected high-impact systems have mitigated GAO's technical findings and updated their security assessment plans for future assessments; NASA is working with GAO to provide necessary documentation to validate closure of these recommendations. NASA is updating its continuous monitoring strategy to align with performance measures from the National Institute of Standards and Technology (NIST) and are targeting completion and publication of these measures by the end of January, 2019.

For GAO-18-337, NASA has three cybersecurity management recommendations that are currently in progress. These pertain to: (1) establishing a cybersecurity strategy; (2) establish an information security program plan (ISPP); and, (3) establishing clearly defined security policies and procedures. Enabling all three recommendations, NASA recently hired a Chief Cyber Risk Officer to establish and oversee agency-wide cybersecurity risk management initiatives. Activities currently underway include leading a NASA Cybersecurity Integration Team (CIT) to address key cybersecurity management challenges, clarifying security policies to reflect current practices, and maturing risk management operations. NASA has also completed the ISPP. The ISPP, after review by the NASA Administrator and OMB, was signed by the NASA CIO on November 1st, 2018. It is now in the publication and Congressional notification cycle. Lastly, NASA's review of its security policy management framework to facilitate consistent reviews is projected to complete by March 2019.

Question 4. Multiple audits issued by the NASA Office of Inspector General, including in February 2012 and more recently May 2018, provided several recommendations to improve the Security Operations Center which have not been implemented by NASA. The OIG found "since its inception a decade ago, the SOC has fallen short of its original intent to serve as NASA's cybersecurity nerve center." What steps has NASA taken to improve the detection and mitigation of cyber incidents across NASA, including strengthening the Security Operations Center?

Answer 4. NASA has taken multiple steps to address and improve the NASA Security Operations Center (SOC) capabilities, governance and responsiveness. The OIG audit recommendations, including those in OIG-18-020, Audit of NASA's Security Operations Center, are key considerations in these on-going improvement efforts. The improvement actions include establishing a SOC continuity of operations / high availability (COOP/HA) capability that include essential functions, critical services and components, performing an Agency-wide assessment of storage solutions to support Agency incident detection and response capabilities to identify data logging, data analytics and data correlation needs, and developing a charter for the NASA SOC that addresses the SOC's organizational placement, purpose, authority, and responsibilities. Among other governance improvements are the greater direct involvement in SOC operations by the Agency CIO and the Agency Senior Agency Information Security Officer (SAISO). Examples of this include multiple visits by these senior Agency officials to the SOC to assess their operations and work with the Ames Research Center leadership to institute organizational improvements.

The NASA SOC implemented enhancements and improvements in the operations of its three key core cybersecurity services: Monitoring and Detection; Incident Mitigation and Prevention; and Reporting and Communications. Network monitoring was enhanced by implementing and monitoring intrusion detection capabilities, between NASA's mission networks and the Internet, in order to assess the risk of the Agency's high value assets. Endpoint monitoring capability was implemented directly on NASA computers allowing for the detection of compromised NASA systems within encrypted network environments and outside on NASA networks. Leveraging external threat information, the NASA SOC successfully reduced the number of phishing compromises at the Agency through enhanced email protection. NASA SOC implemented an Agency-wide intrusion prevention system that blocks numerous attacks against the Agency's infrastructure daily. These efforts resulted a measured decrease in malicious code infection across NASA, as evidenced by the chart below, showing the incident information for FY17 and FY18.

Category	Name	Description	Number of FY17 Incidents	Number of FY18 Incidents
CAT 1	Unauthorized Access	In this category, an individual gains logical or physical access without permission to a Federal agency network, system, application, data, or other resource, including lost hardware.	745	214
CAT 2	Denial of Service (DoS)	An attack that successfully prevents or impairs the normal authorized functionality of networks, systems, or applications by exhausting resources. This activity includes being the victim or participating in the DoS.	21	7
CAT 3	Malicious Code	Successful installation of malicious software (e.g., virus, worm, Trojan horse, or other code-based malicious entity) that	344	76

		infects an operating system or application.		
CAT 4	Improper Use	A person violates acceptable computing use policies.	173	8
		Total	1,283	305

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

February 14, 2019

Reply to Attn of: OLIA/2018-00552:SWQ:dac

The Honorable Jim Cooper
Chairman
Subcommittee on Strategic Forces
Committee on Armed Services
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Representatives Bera, Coffman, Duncan, Foster, Mitchell, and Perlmutter, resulting from the June 22, 2018, hearing entitled, ***"Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities."***

This material completes the information requested during that hearing.

Sincerely,

Suzanne M. Gillen

Suzanne M. Gillen
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosures

Questions submitted by Bera, Ami
Space Situational Awareness: Whole of Government Perspectives on
Roles and Responsibilities
Friday, June 22, 2018

Questions for the Honorable James Bridenstine

Question 1:

Space Policy Directive-3 directs you to update the U.S. Orbital Debris Mitigation Standard and establish new guidelines for satellite design and operation. How do you plan to carry out this new direction? In light of the International de facto acceptance of the standard, what are the challenges associated with updating this standard? How would you envision coordinating satellite design guidelines with non-U.S. government entities, including commercial operators?

Answer 1:

Under the auspices of Space Policy Directive-3 (SPD-3), NASA is leading an interagency forum to update the U.S Government Orbital Debris Mitigation Standard Practices. This whole of government effort includes participation by the regulatory agencies -- Departments of Transportation and Commerce, and the Federal Communications Commission -- so that they will have a sound scientific and technical basis for developing orbital debris mitigation policies and regulations for their respective commercial licensing regimes. A key element of SPD-3 acknowledges the importance of international engagement on Space Situational Awareness (SSA) and Space Traffic Management (STM) issues, noting that spaceflight safety is a global challenge requiring international transparency and STM data sharing. Consequently, the State Department is leading the effort to ensure international transparency, promoting best practices for space safety and the preservation of the space environment and international engagement on SSA and STM issues through bilateral and multilateral international engagements.

Question 2:

Should the U.S. partner with non-U.S. government and commercial entities to receive and provide SSA data, information, and services, and if so, how? How would non-U.S. government data sources be validated? What would be involved in "fusing" tools and services provided by non-U.S. government and commercial with existing federal government services provided to civil operators? How should liability issues be handled?

Answer 2:

SPD-3 envisions a cooperative construct--with both U.S. domestic commercial and non-U.S. government entities, among others, contributing SSA data to a common pool, from which shared data may be mined by those contributors and used for their own SSA sharing applications. Potential issues regarding data integrity, integration, and liability will be considered by the Department of Commerce as it develops its STM concepts and mechanisms.

Question 3:

What agencies within the Federal government currently carry out research on SSA and orbital debris and to what extent are those activities coordinated? How could such work be leveraged in a civil, operational SSA system?

Answer 3:

While NASA cannot speak to the specific budget investments of others, we would note that SPD-3 has a goal of advancing U.S. SSA and STM science and technology. SPD-3 further indicates that Departments and agencies are to "coordinate, prioritize and advocate" for science and technology, SSA and STM, as appropriate, as it relates to their mission." NASA will comply with this guidance, in coordination with the National Space Council.

QFR submitted by Coffman, Mike
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on
Roles and Responsibilities
Friday, June 22, 2018

Question for the Honorable James Bridenstine

Question 3:

Are you concerned this new need for space funding will cannibalize from NASA budgets?

Answer 3:

Space Policy Directive-3 (SPD-3), *National Space Traffic Management Policy*, recognizes that after more than 60 years of human space activities, orbital debris has become a serious problem to space operations. SPD-3 highlighted the need to advance space situational awareness and improve the fundamental knowledge of the space environment, such as the characterization of small debris. NASA will continue to prioritize requirements within available budget constraints, while striving to achieve SPD-3 objectives.

QFR submitted by Hunter, Duncan
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for the Honorable James Bridenstine

Question 1:

Administrator Bridenstine, the 2013 National Space Transportation Policy calls for the use of U.S. rockets for U.S. government payloads with some minor exceptions that perhaps should be revisited anyway. President Trump's Space Policy Directive-2 directs the executive branch to "encourage American leadership in space" and "promote economic growth." The U.S. currently has a competitive space launch industry, yet NASA payloads continue to fly on foreign launch vehicles even those that are subsidized by foreign governments. Could NASA better promote the goals of the National Space Transportation Policy and Space Policy Directive-2 by using American rockets to launch American satellites? Should we have a "Buy American Fly American" policy?

Answer 1:

NASA believes existing statute and policy supports a "Buy American Fly American" objective. NASA complies with 51 USC 50131, the 2013 National Space Transportation Policy, and Space Policy Directive-2 for the launch services it procures and uses in support of Agency payload missions, with regard to both the launch vehicle and the provider of the launch service.

51 USC §50131 requires the U.S. Government to procure space transportation services from domestic commercial providers, with a few specific exceptions. The National Space Policy also requires the U.S. Government to use U.S. commercial space transportation services. NASA procures launch services in accordance with existing law and policy.

In addition, NASA does not buy foreign launch vehicles for the launch of its satellites or science missions. United States Government payloads are to be launched on space launch vehicles manufactured in the United States, unless exempted by the Director of the Office of Science and Technology Policy and the Assistant to the President for National Security Affairs through an interagency process. This policy, however, does not apply to use of foreign launch vehicles on a no-exchange-of-funds basis to support the following: flight of scientific instruments on foreign spacecraft, international scientific programs, or other cooperative government-to-government programs. A primary example of the application of this exception is the James Webb Space Telescope (JWST), for which the European Space Agency (ESA) has agreed to provide an Ariane 5 launcher and associated launch services to NASA as part of the European contribution to the mission.

QFR submitted by Foster, Bill
Space Situational Awareness: Whole of Government Perspectives on
Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine

Question 1:

As you know, NASA is currently advancing various nuclear reactors for deep-space missions, particularly to Mars. One is for spacecraft propulsion, which would utilize low-enriched uranium. The second is for surface power, which would utilize highly-enriched, or weapons-grade, uranium.

Highly-enriched uranium is one of the most dangerous materials on Earth because of its direct significance for potential use in nuclear weapons and acts of nuclear terrorism, which is why the elimination of globally held stockpiles has been a long-standing U.S. policy objective. This is a point highlighted by NASA's Marshall Space Flight Center, which is leading the development of the propulsion reactor utilizing low-enriched uranium.

Furthermore, the utilization of HEU in any space reactor would result in considerable security-related costs, inhibit the participation of commercial and academic partners for development and testing, and establish precedent for other countries to justify their own HEU programs.

Administrator Bridenstine, could you comment as to what the disconnect is between the two development teams?

Answer 1:

As noted, NASA has two major efforts devoted to fission systems, with Department of Energy (DOE) as a key partner on both. The Kilopower project, devoted to small reactors for planetary surface power and potentially planetary science missions, recently tested a 1 kilowatt (electric) High Enriched Uranium (HEU)-based fission system at the Nevada National Security Site. Long-lived, continuous day and night power sources on the lunar surface are important to promote meaningful in situ resource utilization-based propellant production, and to deliver enough power to support human surface presence through multiple day-night cycles. NASA's Kilopower project is projected to provide the most mass effective and logistically-simple solution to meet those mission goals. The Nuclear Thermal Propulsion (NTP) project, which has adopted an low enriched uranium-based reactor design, is addressing key technical challenges related to developing an efficient propulsion system for deep space transit.

NASA recognizes the importance of developing space fission systems that use Low Enriched Uranium (LEU) where it is technically practical. These widely differing concepts of operations drive requirements on the respective fission systems that include mass, volume, power level, thermal management, and operational parameters; these in turn impact the entire mission architecture (including launch vehicles, spacecraft, landers, and surface installations). Such requirements, along with fundamental scaling physics, drive the choice of fission fuel form and enrichment.

The use cases for the space fission system technologies being developed by the two projects are dramatically different. Surface power systems such as Kilopower, initially with power levels of perhaps a few kilowatts scaling up to several tens of kilowatts, would be delivered to lunar or other planetary surfaces on a lander with that landing system driving mass constraints. After deployment, the system would be expected to operate continuously for many years. By contrast, an NTP system, with a reactor power level of several hundred megawatts, would be used for the main propulsion of a large spacecraft, executing a few high-performance propulsive maneuvers with run times of several minutes to a few tens of minutes, used mainly to depart one planetary body (for example, Earth) and capture into orbit around another (such as Mars).

Landed mass is an especially important parameter for systems that must be delivered to planetary surfaces. Generally, fission systems at power levels under about 100-150 kilowatts will be less massive if utilizing HEU. For systems in the range of a few kilowatts to a few tens of kilowatts, that mass advantage becomes quite substantial (several hundred kilograms). Since LEU may offer advantages relative to ground handling and launch security and despite the known mass pentalities, NASA is executing a trade study in FY 2019 to establish a comprehensive basis for comparison of the technical, cost, safety, security, and policy considerations for small space fission systems utilizing LEU and those utilizing HEU. This trade study assures that NASA's space fission development efforts not only satisfy system and mission design considerations, but also address the relevant policy, security, safety, and partnership implications.

QFR submitted by Mitchell, Paul
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for the Honorable James Bridenstine

Question 10:

Administrator Bridenstine, you testified that the Federal Aviation Administration (FAA) has already been involved in discussions about Space Situational Awareness (SSA) and Space Traffic Management (STM). Can you detail how the National Aeronautical and Space Administration (NASA) has worked with the Department of Transportation (DoT) and the FAA previously - both during your tenure and before?

Answer 10:

The FAA has held informal discussions with NASA, among other space operators, about the Agency's internal methods for conjunction assessment risk analysis for both robotic and human spacecraft. However, these information exchanges were all informal; there is no formal agreement between NASA and the FAA focused on SSA or STM activities.

Question 11:

You testified that you support the Department of Commerce leading this mission as Space Policy Directive - 3 calls for, but you also acknowledged that the FAA has special expertise in managing air traffic already. How does your agency intend to work with the FAA on SSA and STM moving forward?

Answer 11:

Under the auspices of SPD-3, NASA is leading an interagency effort to update the U.S. Government Orbital Debris Mitigation Standard Practices so that that regulatory agencies Departments of Transportation and Commerce or the Federal Communications Commission -- have a sound scientific and technical basis for developing orbital debris mitigation policies and regulations for their respective commercial licensing regimes. NASA also has expertise in conjunction assessment risk analysis within our human and robotic space missions and will provide inputs relative to best practices to help inform DoT and DoC efforts.

Question 12:

General Hyten testified that when it comes to space, every element of the government is involved and that means there are going to be seams. He said that the seams are best addressed by establishing clear authorities and responsibilities. Can you provide more detail on how authorities and responsibilities are going to be handled among the partners identified in Space Policy Directive 3, especially the Department of Transportation?

Answer 12:

NASA would respectfully defer to the SPD-3, the first National Space Traffic Management Policy for a detailed and comprehensive outline of roles and responsibilities within the interagency, both currently and in future, as the Department of Defense transitions some roles to the Department of Commerce. The Department of Transportation will retain its current role of regulation of commercial launch, landing and spaceports.

Question 13:

Both space and traditional commercial airspace traffic have some interplay, how are you resolving that issue? How are you working with FAA to address that specific seam?

Answer 13:

Launch and landing are where spaceflight interfaces with the U.S. National Airspace and its air traffic. NASA is a partner in a four-agency coordination group (Air Force Space Command, National Reconnaissance Office, FAA, NASA) that consider, among other launch and landing topics, how to address joint use between the launch ranges and the National Airspace as the number of commercial launch ranges and the frequency of commercial space launches is expected to increase.

Question 14:

How does NASA envision Space Situational Awareness and Space Traffic Management playing out in practice? Will this be handled by a government agency or is this an authority that could be given to another type of non-governmental entity?

Answer 14:

The SPD-3 outlines a thoughtful and practical approach for implementing an improved future construct for Space Traffic Management, including Space Situational Awareness. SPD-3 does not limit involvement in STM and SSA activities and products to government agencies. As with any proposed approach, NASA and the rest of the interagency will make adjustments along the way as appropriate and as circumstances warrant.

QFR submitted by Perlmutter, Ed
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for the Honorable James Bridenstine

Question 1:

With the additional responsibilities directed at the Department of Commerce under Space Policy Directive-3 (SPD-3), how does NASA plan to support DOC through the use of detailed personnel, trainings, or other methods as the DOC relies on NASA's expertise to stand up these new responsibilities?

Answer 1:

Under the auspices of SPD-3, NASA is leading an interagency working group to develop updated U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP) in coordination with the Department of Commerce, and other Federal agencies, so that Commerce has credible and practicable practices and standards from which they might derive regulations governing their licensing activities. NASA also is supporting the Department of Commerce with expertise and advice on those aspects of SPD-3 for which Commerce has a lead role, again through an interagency working group construct which includes the inputs and expertise from other Federal agencies as well. To date, Commerce has not requested that NASA make available detailed civil servants to advance their particular efforts. If such a formal request is made in the future, NASA would consider how to support our Commerce colleagues, as appropriate.

COMMITTEE ON ARMED SERVICES

U.S. House of Representatives

Washington, DC 20515–6035

ONE HUNDRED FIFTEENTH CONGRESS

October 18, 2018

The Honorable James Bridenstine
Administrator
National Aeronautics and
Space Administration
300 E Street SW
Washington, D.C. 20546

Dear Mr. Bridenstine:

Thank you for appearing before the House Armed Services Subcommittee on Strategic Forces on June 22, 2018. Your participation added a valuable perspective to the subcommittee's understanding of whole of government approaches to space situational awareness. As you know, the entire hearing was transcribed and will be published as part of the hearing record.

Enclosed you will find a copy of questions which have been submitted for the record. As this information is of great value to the subcommittee, I ask that your responses be provided to Ms. Danielle Steitz, of the committee staff, by November 18, 2018. The responses should be provided electronically to danielle.steitz2@mail.house.gov. If the subcommittee has not received your responses by this date, the hearing publication will be printed with an appropriate notation.

Again, I appreciate your participation.

Sincerely,

Mike Rogers

Mike Rogers
Chairman
Subcommittee on Strategic Forces

QFR submitted by Hunter, Duncan
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
1) Administrator Bridenstine, the 2013 National Space Transportation Policy calls for the use of U.S. rockets for U.S. government payloads, with some minor exceptions that perhaps should be revisited anyway. President Trump's Space Policy Directive 2 directs the executive branch to "encourage American leadership in space" and "promote economic growth." The U.S. currently has a competitive space launch industry, yet NASA payloads continue to fly on foreign launch vehicles, even those that are subsidized by foreign governments. Could NASA better promote the goals of the National Space Transportation Policy and Space Policy Directive 2 by using American rockets to launch American satellites? Should we have a "Buy American, Fly American" policy?

Gen. Hyten, as DOD looks to purchase more commercial data and services, do you agree that these should be purchased from entities that launch from American spaceports

No Answer

QFR submitted by Coffman, Mike
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
3) Are you concerned this new need for space funding will cannibalize from NASA budgets?

No Answer

QFR submitted by Mitchell, Paul
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
10) Administrator Bridenstine, you testified that the Federal Aviation Administration (FAA) has already been involved in discussions about Space Situational Awareness (SSA) and Space Traffic Management (STM). Can you detail how the National Aeronautical and Space Administration has worked with the Department of Transportation and the FAA previously – both during your tenure and before

No Answer

QFR submitted by Mitchell, Paul
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
11) You testified that you support the Department of Commerce leading this mission as Space Policy Directive – 3 calls for, but you also acknowledged that the FAA has special expertise in managing air traffic already. How does your agency intend to work with the FAA on SSA and STM moving forward?

No Answer

QFR submitted by Mitchell, Paul
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
12) General Hyten testified that when it comes to space, every element of the government is involved and that means there are going to be seams. He said that the seams are best addressed by establishing clear authorities and responsibilities. Can you provide more detail on how authorities and responsibilities are going to be handled among the partners identified in Space Policy Directive 3, especially the Department of Transportation?

No Answer

QFR submitted by Mitchell, Paul
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
13) Both space and traditional commercial airspace traffic have some interplay, how are you resolving that issue? How are you working with FAA to address that specific seam?

No Answer

QFR submitted by Mitchell, Paul
Subcommittee on Strategic Forces
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
14) How does NASA envision Space Situational Awareness and Space Traffic Management playing out in practice? Will this be handled by a government agency or is this an authority that could be given to another type of non-governmental entity?

No Answer

QFR submitted by Perlmutter, Ed
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
With the additional responsibilities directed at the Department of Commerce under SPD3, how does NASA plan to support DOC through the use of detailed personnel, trainings, or other methods as the DOC relies on NASA's expertise to stand up these new responsibilities?

No Answer

QFR submitted by Foster, Bill
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
As you know, NASA is currently advancing various nuclear reactors for deep-space missions, particularly to Mars. One is for spacecraft propulsion, which would utilize low-enriched uranium. The second is for surface power, which would utilize highly-enriched, or weapons-grade, uranium.

Highly-enriched uranium is one of the most dangerous materials on Earth because of its direct significance for potential use in nuclear weapons and acts of nuclear terrorism, which is why the elimination of globally held stockpiles has been a long-standing U.S. policy objective. This is a point highlighted by NASA's Marshall Space Flight Center, which is leading the development of the propulsion reactor utilizing low-enriched uranium.

Furthermore, the utilization of HEU in any space reactor would result in considerable security-related costs, inhibit the participation of commercial and academic partners for development and testing, and establish precedent for other countries to justify their own HEU programs.

(1)Administrator Bridenstine, could you comment as to what the disconnect is between the two development teams?

No Answer

QFR submitted by Bera, Ami
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
Space Policy Directive-3 directs you to update the U.S. Orbital Debris Mitigation Standard and establish new guidelines for satellite design and operation. How do you plan to carry out this new direction? In light of the international de facto acceptance of the standard, what are the challenges associated with updating this standard? How would you envision coordinating satellite design guidelines with non-U.S. government entities, including commercial operators?

No Answer

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Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

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Should the U.S. partner with non-U.S. government and commercial entities to receive and provide SSA data, information, and services, and if so, how? How would non-U.S. government data sources be validated? What would be involved in "fusing" tools and services provided by non-U.S. government and commercial with existing federal government services provided to civil operators? How should liability issues be handled?

No Answer

QFR submitted by Bera, Ami
Space Situational Awareness: Whole of Government Perspectives on Roles and Responsibilities
Friday, June 22, 2018

Question for: The Honorable James Bridenstine
What agencies within the Federal government currently carry out research on SSA and orbital debris and to what extent are those activities coordinated? How could such work be leveraged in a civil, operational SSA system?

No Answer

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

June 18, 2019

Reply to Attn of: OLIA/2019-00080:SWQ

The Honorable Roger Wicker
Chairman
Committee on Commerce, Science,
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by you, Ranking Member Cantwell, Senators Murray, Scott and Thune resulting from the March 13, 2019, hearing entitled, "The New Space Race: Ensuring U.S. Global Leadership on the Final Frontier."

This material completes the information requested during that hearing.

Sincerely,

Suzanne Gillen

Suzanne M. Gillen
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosure

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
"The New Space Race: Ensuring U.S. Global Leadership on the Final Frontier"
March 13, 2019

Written Question Submitted by Hon. Roger Wicker to Hon. Jim Bridenstine

Question 1. Administrator Bridenstine, commercial satellite broadband operators continue to build, launch and operate increasingly high-capacity satellites. Does NASA intend on greater usage of commercial satellite communications to meet its communications requirements? Please share your perspective on the importance of ensuring that commercial satellite communications companies will continue to have reasonable access to critical spectrum bands.

Answer 1. NASA's FY20 budget request initiates the Communications Services Program (CSP) to begin purchasing commercially provided satellite-based data relaying services to more efficiently meet future needs. As an initial activity, the CSP will pursue opportunities that will allow future NASA missions to deploy flight-qualified capabilities for near-Earth users to get support from commercial providers. Over a longer time horizon, the CSP will be responsible for the acquisition management of the next-generation operational communications capability as current Tracking and Data Relay Service (TDRS) satellites are retired. CSP will work with the commercial market to identify requirements and explore opportunities that are mutually beneficial to NASA and industry, and will develop an acquisition model for incorporating commercial communications services into operations.

NASA will define the acquisition strategy for transitioning near-Earth NASA users to suitable commercially provided services. This acquisition strategy could include commercial service contracts, hosted payloads, and/or public-private-partnerships. NASA expects to partner with multiple commercial entities to phase out reliance on NASA-owned and -operated systems. This will bolster American industry, significantly reduce the cost of communication services to NASA, and maximize interoperability between Government and commercial service providers while promoting a diverse commercial market.

As the Communication Services Program expands NASA's use of commercially provided communications services, the spectrum used to support these services will become increasing important to the agency. Electromagnetic spectrum is a valuable and limited natural resource that all NASA missions require for communications, navigation, remote sensing, and data services in the areas of Earth science, space science, human space exploration, and aeronautical research. All forms of wireless communication systems used by the U.S. Federal Government or by commercial entities use the electromagnetic spectrum, so the spectrum must be carefully controlled and coordinated. The Human Exploration and Operations (HEO) Mission Directorate's Space Communications and Navigation (SCaN) Division is responsible for ensuring access to the portions of electromagnetic spectrum necessary to support NASA's mission needs. In both the domestic and international arenas, NASA continues to engage with the commercial sector to identify more flexibility in the use of spectrum resources that will meet mission objectives for the entire space community. SCaN will focus on planned agenda items at the World Radiocommunication Conference in FY20, and working within the U.S. Delegation, will seek to ensure continued access to the RF spectrum supporting NASA's mission requirements, the U.S. Government space interests, and the U.S. commercial space community.

Questions for the Record
"Global Space Race: Ensuring U.S. Global Leadership on the Final Frontier"
Ranking Member Maria Cantwell

Written Questions Submitted by Hon. Maria Cantwell to Administrator James Bridenstine:

NEOWISE. NEOWISE's goal is to identify comets and asteroids that may potentially pose a threat to our world. However, there are concerns that much of the data that NASA collected is inaccurate due to a software bug that was not disclosed to public researchers for many years, significantly setting back their efforts to advance the NEOWISE mission. Additionally, there is a proposed mission to launch a new telescope into space to support the program known as the Near-Earth Object Camera (NEOCAM), which will cost about $600M. However, there's a ground observatory, the Large Synoptic Survey Telescope (LSST), which is nearing completion in Chile. LSST will accomplish many of the same goals as NEOCAM, and will be up and running before NEOCAM's planned launch. Needless to say, I have concerns about the management of this program. I want to make sure that the best possible science is being done on this issue, and that taxpayer resources are being used well.

Question 1. Can you address these concerns about a potential software bug?

Answer 1. The NEOWISE science team, in 2011, discovered an inconsistency in the mathematical model that was used to compute estimated sizes of observed asteroids, based on the infrared energy collected by spacecraft sensors. At times referred to as a "software bug", in actuality this was a mathematical inconsistency in the size estimation software used. The NEOWISE spacecraft, its operations, or the infrared data it collected were not affected. Rather, this pertained to a small percentage of the observed object physical size estimates in the scientific analysis of the collected NEOWISE data. Size estimates are affected by many different factors; this effect was less than ±6 percent, well within the estimated accuracy of ±20 percent articulated by the NEOWISE science team. The NEOWISE team corrected this issue for the 2011 thermal model, thus it affected only some size estimate analyses that used data collected during the WISE prime mission (Jan. 2010 – Feb. 2011). The NEOWISE team brought the issue to the attention of other researchers when updates to their estimated sizes were published in the NEOWISE database in 2014. Such corrections and updates are part of the normal scientific process; this being one of several thermal model improvements made over eleven years of project-work. Many other asteroid scientists have conducted independent studies of asteroid sizes and validated the NEOWISE results. NASA has no concerns regarding the efficacy of the science team, the data or any future mission that could go forward based on NEOWISE. In fact, experiences such as this confirm the invaluable service of NASA mission science teams, and only serve to improve the scientific results obtained by missions.

Further, NASA has funded an independent study by the National Academies of Sciences, Engineering and Medicine (NASEM) entitled "Near Earth Object Observations in the Infrared and Visible Wavelengths," found here:
(https://www8.nationalacademies.org/pa/projectview.aspx?key=51478). The investigation will 1) explore the relative advantages and disadvantages of IR and visible observations of near Earth objects (NEOs), 2) review and describe the techniques that could be used to obtain NEO sizes

from an infrared spectrum and delineate the associated errors in determining the size, and 3) evaluate the strengths and weaknesses of these techniques and recommend the most valid techniques that give reproducible results with quantifiable errors. The study team is well into the investigation with the published report expected by early summer 2019.

With regard to the National Science Foundation (NSF) Large Synoptic Survey Telescope (LSST), NASA and NSF formed a joint study team to assess its potential contribution to the discovery of NEOs once LSST becomes operational in 2023. The team, which included members of the LSST science team, extensively examined the potential LSST capabilities and published findings in a March 2017 paper, found here: https://www.nasa.gov/sites/default/files/atoms/files/joint_jpl-uw_whitepaper_27mar2017.pdf. The effort was conducted in parallel with a NASA Science Mission Directorate (SMD)-sponsored NEO Science Definition Team (SDT) that provided a non-advocate technical report in September 2017, found here: (https://www.nasa.gov/sites/default/files/atoms/files/2017_neo_sdt_final_e-version.pdf). The NEO SDT assessed performance of current NEO survey assets and addressed options for optimizing the effort into the future. The SDT found that by the early 2030s current ground-based NEO search efforts will reach approximately 60 percent completeness of the statutory goal of finding at least 90 percent of NEOs greater than or equal to 140 meters. According to the joint NASA/NSF study, the LSST would accelerate the discovery rate to approximately 75-80 percent completeness of the goal in the ten years of planned operations by NSF (i.e., by the mid-2030s), and would improve this completeness by 1-2 percent for each year of additional operations. LSST would not be expected to achieve 90 percent completeness until well into the 2040s.

The NEOCAM mission concept has been studied for several years, but has not been approved to proceed. NASA is currently assessing whether a space-based survey capability such as NEOCAM is warranted. The SDT found that a space-based survey capability could accelerate reaching the statutory goal, and this capability also could provide a more accurate estimate of sizes if it operated in the infrared wavelengths, which cannot be done by ground-based survey telescopes.

Question 2. Will you commit to working with me and my staff to make sure this important mission is being managed in a way that successfully accomplishes its goals?

Answer 2. Yes, NASA is committed to the goals of our Planetary Defense Program and would be pleased to answer any additional questions you may have. The extent of NASA's current efforts is delineated at https://www.nasa.gov/planetarydefense/overview, and daily progress at finding the NEO population can be tracked here: https://cneos.jpl.nasa.gov/stats/totals.html.

Space Launch System – First Mission. You spoke about possibly flying Orion on a commercial vehicle. I am concerned that pushing SLS further out will kill the program. Furthermore, there are safety concerns related to flying SLS for the first time with crew.

Question 1. What are the other options you referenced?

Answer 1. In March 2019, in an effort to ensure that NASA stays on track for the launch of Artemis 1 by 2020, the Agency explored the possibility of launching Orion and the European Service Module (ESM) to low-Earth orbit (LEO) on an existing rocket, then using a boost from another existing vehicle for Trans Lunar Injection. Among options considered were launching on: a single Delta IV Heavy; two Delta IVs; a Delta IV and a Falcon Heavy; and a Falcon Heavy with Interim Cryogenic Propulsion Stage (ICPS). Although the preliminary assessment showed that it might be possible to launch Orion on a single Falcon Heavy, such a configuration would also pose significant integration, procurement, and technical challenges. Therefore, the Agency determined that the best option was to work to accelerate development of the Space Launch System (SLS) to stay on track for an Artemis 1 launch in 2020. We are continuing to investigate commercial options for later missions. Having dissimilar redundancy (e.g., two launch vehicles) has been proven important to long-term safe operations. Examples include: Soyuz as a back-up to the Space Shuttle; Atlas V as a back-up to Antares.

Question 2. What can we do to ensure the Space Launch System (SLS) is ready to launch Orion in 2020?

Answer 2. The NASA and Boeing teams are working overtime to prevent ongoing delays to the launch schedule of the SLS from pushing the first launch into 2021. On March 4, 2019, NASA's Human Exploration and Operations (HEO) Mission Directorate chartered an assessment of other activities needed to achieve a launch in 2020. After completion of the HEO assessment, an independent schedule risk review led by the NASA Office of the Chief Financial Officer (OCFO) will assess the proposed new plan.

Question 3. Please explain the safety issues related to flying SLS for the first time with crew and how the agency plans to mitigate those risks.

Answer 3. NASA is not planning for the first flight of SLS to be a crewed flight. The second flight of SLS will be the first crewed flight, Artemis 2, and NASA is executing a multi-step integrated test and training program to plan and execute this mission, and those that follow, with minimum risk to crew and mission objectives.

In addition to extensive ground testing of hardware and systems, NASA will test abort operations with the Ascent Abort test 2 (AA-2) in June 2019. The Artemis 1 test flight will provide additional critical data that will be used to validate the rocket design and refine mission operations prior to the crewed Artemis 2 flight.

NASA has designed Artemis 2 to minimize exposure to orbital debris before the Orion crew heads off for its trip beyond the Moon and back. NASA is conducting extensive training for its astronauts and ground crew that will enable coordinated responses to a host of contingency operations.

Space Launch System – Program Cuts. I am surprised that this budget cuts NASA's key exploration systems, SLS and Orion, leading up to the first integrated launch in 2020. I am also concerned that NASA is deferring development of SLS's Enhanced Upper Stage.

Question 1. How will these proposed cuts impact the planned once a year launch cadence for SLS and Orion and the long-term goals of the exploration program?

Answer 1. NASA's baseline plan has been to launch Artemis 1 in 2020, followed by Artemis 2 in 2022, and the third flight in 2024 with launches once per year thereafter. The FY 2020 Budget provided the resources needed to achieve this launch cadence and the May Budget Amendment added over $600M to keep the program on track. NASA is committed to meeting the current launch manifest and is focusing efforts to overcome core stage first-time production issues, which have slowed efforts to procure hardware for the third flight and beyond. While NASA is resolving near-term core stage production issues, risk to the one-year flight cadence is being mitigated by funding long-lead procurements. NASA continues to evaluate and work these challenges to meet its manifest commitments, including the new challenge of landing astronauts on the Moon by 2024.

Question 2. Why is NASA deferring development of the Enhanced Upper Stage when this capability is needed to maintain robust and sustainable deep space exploration?

Answer 2. The development of SLS core stage has proven to be more challenging than previously anticipated. Therefore, the NASA and Boeing teams are currently focused on completing the SLS core stage and accelerating development of the launch vehicle overall in order to ensure that we can fly Artemis 1 in 2020. EUS can be an important future component of our cislunar and deep space capability, but it is critical to complete SLS in the near-term and stay on track with the launch of Artemis 1.

International Space Station. I'm disappointed to see the FY20 budget again includes the administration's proposal to end direct federal funding for the International Space Station by 2025. The NASA Inspector General has called it "highly unlikely" that by 2025 a private company will be able to take over significant portions of the ISS or field a private replacement.

Question 1. Given China's plans to construct their own space station, are you concerned about what would happen to our international partnerships and U.S. leadership in space if we stop funding the ISS in 2025?

Answer 1. The Administration is committed to maintaining access to a platform in low Earth orbit (LEO). NASA intends to transition from the current Government-dominated model of human spaceflight activities in LEO to a model where Government is only one customer for commercial services. The Agency is increasing the breadth and depth of commercial and international LEO activities. NASA will expand partnerships in LEO to include new companies and additional nations beyond the ISS Partners, including working with commercial partners to support visiting crew.

NASA is leveraging the ISS Partnership to define technical interoperability standards for exploration that will allow expanded commercial and international partnerships in LEO and beyond. Our partners are interested in participating in the Gateway and in conducting activities on the lunar surface. While they are willing to work with other nations, the United States remains the preferred partner, given our existing leadership role and the capabilities we contribute to human and robotic space exploration.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
"The New Space Race: Ensuring U.S. Global Leadership on the Final Frontier"
March 13, 2019

Written Questions Submitted by Hon. John Thune to Hon. Jim Bridenstine

Question 1. Administrator Bridenstine, you mentioned the importance of international partnerships to NASA's missions, especially those conducted in low-Earth orbit.

Could you speak to areas where international partnerships benefit and support NASA's satellite operations, particularly when it comes to Earth observation operations?

Answer 1. The NASA Earth Science Division (ESD) engages in, and in some cases pioneers, substantive partnerships and collaborations with other Federal agencies, international agencies and coordination bodies, and with private sector and commercial entities. For international partnerships in particular, the collaborations provide mutual benefit to all parties.

More than half of the on-orbit NASA Earth research satellites, and a substantial fraction of the missions in development for launch over the next four years, involve significant hardware collaborations with international partners. A few examples include: the recently launched Gravity Recovery and Climate Experiment Follow On with Germany, the upcoming NASA-India Synthetic Aperture Radar mission, and the Sentinel-6A/B ocean altimetry missions with the European Space Agency (ESA), the National Oceanic and Atmospheric Administration, the European Commission, and the European Organization for the Exploitation of Meteorological Satellites. Other partners in satellite mission development and/or operations include the space agencies of Japan, France, Germany and Canada. NASA ESD and ESA also coordinate activities related to research and field campaigns, interoperable data systems, and joint satellite mission activities through the NASA-ESA Earth Science Joint Program Planning Group.

Question 2. Administrator Bridenstine, the next satellite in the Landsat program, Landsat 9, is scheduled to be ready for launch in December of next year. This date was confirmed in a report last year by the Government Accountability Office, which determined that the Landsat 9 project was still on schedule for completion by December 2020.

Are there any updates or schedule changes that would lead NASA to believe Landsat 9 will not be ready to launch on time?

Answer 2. The project continues working toward a December 2020 Launch Readiness Date (LRD), 11 months before the Agency Baseline Commitment for a November 2021 launch. The project's next major milestone, Key Decision Point-D (KDP-D), is currently scheduled for December 2019.

"Global Space Race: Ensuring U.S. Global Leadership on the Final Frontier"
Senator Ed Markey

Written Questions Submitted by Hon. Ed Markey to Administrator James Bridenstine:

Space Exploration – World Leader. According to a 2018 Pew study, almost 3 out of every 4 Americans believes that the United States must continue to be a world leader in space exploration, and 4 in 5 say that the space station has been a good investment for the country.

Question 1. Can you guarantee there will be absolutely no interruption of American scientific research in low-Earth orbit if NASA funding of the International Space Station ends after 2024?

Answer 1. The Administration is committed to maintaining access to a platform in low Earth orbit (LEO), so NASA has no concerns about interruptions to international partnerships, U.S. leadership, or scientific research related to the ongoing commercialization of activities in LEO. NASA recognizes the importance of maintaining continued operations and U.S. leadership in low-Earth orbit (LEO). The Agency is working to transition its work in LEO, including our international partnerships, to be based on commercially-provided space station services that help enable deep space exploration and private sector expansion in LEO. To support this transition, the International Space Station (ISS) will focus near-term activities on supporting commercial industry as well as meeting Government requirements in LEO. In parallel, NASA is creating a focused effort aimed at long-term American operations in LEO independent of the ISS.

It is also important to note that NASA is conducting scientific research in LEO and beyond through over 60 operating robotic missions managed by the Science Mission Directorate, including several science instruments on the ISS focused on Earth Science and Astrophysics research.

NASA Budget Cuts and Existing Projects – In a hearing last year, you said, "We are committed to studying planet Earth at NASA." I am disappointed to see that the President's Budget yet again cuts valuable Earth science funding. It proposes to eliminate funding for two projects expected to provide critical new data for understanding climate change and the health of our planet: the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission and the Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder project. In that same hearing, you said, "CLARREO and PACE are, because of the laws passed by this body, they are being built as we speak."

Question 1. Are both these missions still currently under development, despite the Administration's stated intention to cut funding for these programs?

Answer 1. Yes. PACE and CLARREO-PF are still proceeding as planned in accordance with the appropriated budget in the FY19 Consolidated Appropriations Act. CLARREO-PF's Preliminary Design Review (PDR) will be held in May 2019, and its Key Decision Point C (KDP-C) is scheduled for July 9. PACE's PDR will be held in June 2019, and its KDP-C is scheduled for August 15.

Question 2. Do you agree that it is important to maintain the United States' leadership in Earth science at the same time as we seek to keep our leadership in the deep space race?

Answer 2. Yes. The President's Budget Request for FY20 provides for a strong program that will continue NASA's and the country's leadership in spaceborne Earth observations, Earth system science, and space-based applications. NASA's Earth science activities transform measurements and understanding into information products that are used widely to build national resilience, provide societal benefit, and improve lives.

The budget request continues full operations of NASA's fleet of 22 Earth observing research missions in low-Earth orbit, geostationary orbit, Lagrange-1 orbit, and on the International Space Station.

Statement from Past Year. In a hearing last year, you said, "It is my goal as the Administrator of NASA to follow the decadal surveys that we get from the National Academy of Sciences, and that is my objective, to make sure that what we are doing is apolitical and nonpartisan."

Question 1. The CLARREO mission was originally recommended in the 2007 Earth Science Decadal. Do you stand by your commitment last year to follow the recommendations of the decadal surveys?

Answer 1. Yes. The decadal surveys play a leading role in articulating the consensus-driven priorities and needs of the scientific communities we serve and in setting the goals of NASA's Earth Science Division (ESD) satellite mission development. However, the decadal survey is not the sole source of recommendations. The decadal survey recommendations must be balanced with other priorities and constraints, including budget assumptions set by the Administration. The last two Earth science decadal surveys have assumed budgets that were significantly higher than were eventually appropriated. In order to address these recommendations under constrained budgets, ESD is leveraging partnerships, work and ideas from the non-governmental and private sectors, as well as emphasizing competition.

Uranium. A recent white paper from the Los Alamos National Laboratory (LANL) advocated for the use of weapons-grade, highly enriched uranium (HEU) to fuel reactors to provide energy for space flight or on planetary surfaces. This would break longstanding U.S. policy to avoid the use of this uranium in non-weapons applications and it might make projects harder to fund and complete, compared to the use of low-enriched uranium (LEU). It also contradicts the findings of several NASA presentations and fact sheets from preceding years.

Question 1. Is NASA reversing its position on the U.S. policy to minimize the use of HEU in civilian nuclear applications? If yes, why?

Answer 1. In coordination with DoE, NASA is in compliance with U.S. policy relative to the use of HEU for space applications.

Question 2. Has NASA explored using low-enriched uranium and, if so, why was this deemed an unacceptable alternative?

Answer 2. NASA continues to review and evaluate various nuclear technology options, including those that would employ either highly enriched uranium (HEU) or High Assay Low Enriched Uranium (HALEU). The Agency is presently evaluating two different nuclear reactor technology applications for space: 1) nuclear surface power, and 2) nuclear thermal propulsion. The use cases for space fission system technologies being developed by the two projects are significantly different from each other which may lead to different implementations.

Surface power systems, initially with power levels of perhaps a few kilowatts scaling up to several tens of kilowatts, would be delivered to lunar or other planetary surfaces on a lander that has very limited payload capacity. After deployment, the system would be expected to operate continuously for many years. Long-lived, continuous day and night power sources on the lunar surface are essential to promote in situ resource utilization-based propellant production, and to deliver enough power to support human surface sustained presence through multiple day-night cycles. The total mission power to meet near term needs is expected to be less than 10 kilowatts, potentially growing to tens of kilowatts for larger-scale implementations. In this power class, HEU systems offer a considerable mass savings compared to low enriched uranium (LEU) systems. Generally, the mass advantages of HEU-based systems relative to LEU-based fission power systems become significantly reduced at power levels above 100-150 kilowatts. As requirements for surface power systems are finalized and more detailed studies are completed, NASA will be in a position to select the fuel type to best support its missions.

By contrast, a Nuclear Thermal Propulsion system, with a reactor power level of several hundred megawatts, could be used for the main propulsion of a large spacecraft, executing a few high-performance propulsive maneuvers with run times of several minutes to a few tens of minutes. A NASA use for a nuclear thermal propulsion system could be to depart one planetary body (for example, Earth) and capture into orbit around another (such as Mars). NASA's Nuclear Thermal Propulsion project, which has adopted a high-assay low enriched uranium-based reactor design, is addressing key technical challenges related to developing an efficient propulsion system for deep space transit.

Question 3. Since a likely consequence of NASA's use of HEU fuel would be to increase foreign countries' use of HEU fuel and thereby increase the risks of nuclear proliferation and nuclear terrorism, has NASA included such national security costs in its evaluation of HEU fuel? Please provide any estimates, if so.

Answer 3. We recognize that the use of HEU would come with significant costs for security and could also raise broader nonproliferation concerns.
As DOE will retain ownership of the HEU consistent with the Atomic Energy Act, any work done in support of design, fabrication, and transportation will fall under existing security postures at DOE sites. Regarding security costs at the launch location, NASA conducted a Nuclear Power Assessment Study in 2014 that examined the security costs for processing an HEU reactor at the Kennedy Space Center in preparation for launch. That study estimated approximately \$30M (non-recurring) infrastructure investments and \$40M (recurring) for a 9-month campaign that included the required security posture at the launch site. It should be noted that this study utilized conservative assumptions given the specific reactor design was not

finalized, including the quantity and form of HEU. As the reactor designs and mission plans mature, NASA will continue efforts with DOE and other federal agencies to develop a security plan with acceptable performance-based security measures, leveraging to the extent practical existing security programs to minimize security costs where appropriate. These assessments will be factored into the ultimate fuel reactor design decisions.

Question 4. Will using HEU mean that fewer commercial and academic partners would be able to participate in conventional space launches?

Answer 4. While LEU-based systems may facilitate the use of commercial and academic partners to lead the reactor development, an HEU-based reactor development would likely include both commercial and academic partners in support roles. In either case, NASA and DOE would oversee the development for any system employed in a NASA application.

For example, NASA has delivered a number of scientific missions employing nuclear power using commercial launch services, most recently the Mars Science Laboratory in 2011. This rover is successfully operating on Mars and was developed with a variety of international, academic and commercial partners. We anticipate future spacecraft, including those using fission-based reactors as their power source, would continue to support commercial and academic participation in providing scientific instruments, technology and launch vehicles.

Question 5. If yes, has NASA calculated the increase in cost that would come from excluding most potential commercial and academic partners in its valuation of HEU fuel? Please provide any estimates, if so.

Answer 5. Commercial and academic partners would be included in either LEU or HEU reactor developments, as stated above.

Question 6. As you know, facilities using and storing HEU must meet higher regulatory and security standards. Has NASA conducted any studies or estimates of the potential security, administrative, and regulatory costs associated with NASA's potential use of HEU? Please provide any estimates, if so.

Answer 6. The possession and use of HEU falls under the Atomic Energy Act and, as such, DOE would retain ownership and custody of special nuclear materials. The development, testing, and transportation of a HEU power system would be conducted at DOE controlled locations that already possess the necessary security posture. As stated above, the 2014 study provided an initial estimate of the cost to security HEU at the launch location and NASA would work with DOE and other agencies to refine that estimate once the reactor design is finalized.

Question 7. Will you commit to providing my staff more information about why NASA proposes to use HEU and how it reached this decision?

Answer 7. NASA continues to review and evaluate various nuclear technology options, including those that would employ either highly enriched uranium (HEU) or High Assay Low Enriched Uranium (HALEU). NASA is committed to supporting the Committee's oversight.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON
"The New Space Race: Ensuring U.S. Global Leadership on the Final Frontier"
March 13, 2019
Written Question Submitted by Hon. Rick Scott to Hon. Jim Bridenstine

Question 1: The space industry has long been an important and iconic part of Florida's history and economy. In my eight years as Governor, I worked to position Florida as a national and global leader in space exploration by investing more than $230 million in spaceport projects, which supported the creation of more than 1,100 high-paying aerospace jobs since the end of the Shuttle program. Additionally, Florida's Space Coast manufacturers and businesses continue to thrive due to the investments we have made in the space industry.

Administrator Bridenstine, can you discuss any new programs and infrastructure projects at Kennedy Space Center being built in conjunction with our commercial partners and explain their return on investment over the next year? How many new direct and indirect jobs will these projects support? What are some ways we can continue to bridge the gap between NASA and our commercial partners?

Answer 1: NASA Kennedy Space Center (KSC) recently executed three new land leases, utilizing NASA's Enhanced Use Leasing authority, with major commercial partners – SpaceX, Blue Origin, and Florida Power and Light (FPL). Blue Origin's lease will allow for expansion of its current Exploration Park facilities for the purpose of launch vehicle design, manufacturing, assembly, processing, and testing; flight crew and space flight participant training; public engagement and outreach; and mission control and engineering activities. Likewise, SpaceX's lease will allow it to build facilities for the purpose of hardware and launch vehicle design, manufacturing, assembly, processing, and testing; and launch control. FPL's lease will allow it to build a solar farm that will serve the public utility grid.

NASA KSC also has numerous other agreements that allow commercial space launch activities at KSC including SpaceX's operations at the historic Launch Complex 39A, and Space Florida's agreement to operate the historic Shuttle Landing Facility runway. Finally, NASA KSC, through its Space Act Authority, enables commercial space activity by making unique KSC resources and launch services available to its resident commercial partners including SpaceX, Blue Origin, Boeing, and United Launch Alliance (ULA). These partners could not operate or launch at KSC without this support.

NASA's partnerships with commercial space and other compatible industry partners have served as an integral part of the success thus far in managing the challenges of maintaining and transforming the Agency's aging infrastructure. NASA Centers such as KSC continue to seek avenues for mutually beneficial engagement with the commercial sector through agreements that align with and complement the Agency's mission activities and support these infrastructure goals. A well-functioning, efficient and cost-effective infrastructure is necessary for the support of NASA's mission requirements, and is also important for remaining relevant and attractive to potential partners who may be considering relocation or co-location of operations, or investment in development of unutilized real property. The availability of sufficient resources for NASA to meet the challenges of sustaining its infrastructure remains more critical than ever. NASA's FY 2020 budget request includes critical new funding to address these significant challenges with facilities at NASA Centers. This funding will be important to enable NASA Centers to undertake the actions that carry the Agency forward toward its infrastructure management objectives, including replacing obsolete capabilities with facilities that meet the demands of the missions of tomorrow.

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

December 3, 2019

Reply to Attn of: OLIA/2019-00092:RI:dac

The Honorable Eddie Bernice Johnson
Chairwoman
Committee on Science, Space,
and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairwoman Johnson:

Enclosed are responses to written questions submitted by you, and Representatives Horn, Babin, Bonamici, Sherrill, Perlmutter, Tonko, Foster, Crist, Casten, Wexton, Waltz, and Beutler resulting from the April 2, 2019, hearing entitled, "A Review of the NASA Fiscal Year 2020 Budget Request."

This material completes the information requested during that hearing.

Sincerely,

Suzanne M. Gillen

Suzanne M. Gillen
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosure

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:
Administrator Bridenstine
Submitted by Congressman Tonko

Question 1:

What kind of research, development and demonstration is being done at NASA related to using hydrogen as a fuel?

Answer 1:

Hydrogen in liquefied form (LH2) has been utilized by NASA for decades as a rocket fuel for both main and upper stages of vehicles such as the Saturn V and Space Shuttle, and will be used in NASA's Space Launch System when it is complete. To date, every LH2-powered flight vehicle has used the propellant close to its normal boiling point (i.e., in equilibrium with the atmospheric pressure); however, over the years NASA has investigated the possibility of boosting the energy density of LH2 via different processes by cooling the liquid and/or producing slush mixtures. Recently, the Advanced Exploration Systems (AES) Division funded a research and development effort at Kennedy Space Center (KSC), in collaboration with Glenn Research Center (GRC) and Stennis Space Center (SSC), aimed at demonstrating next-generation liquid hydrogen technologies and operations on a large scale (i.e., relevant scale to a launch pad architecture). This system, deemed the Ground Operations Demonstration Unit for Liquid Hydrogen (GODU-LH2), employed the NASA-pioneered Integrated Refrigeration and Storage (IRAS) technology to achieve such milestones as long-duration, zero-loss storage of LH2, zero-loss LH2 tanker offloads, *in situ* liquefaction, and densification of hydrogen down to the freezing point. In fact, the GODU-LH2 testing resulted in the single largest batch of solid hydrogen ever produced.

Question 1a:

How much is being spent?

Answer 1a:

Over the preceding 5 years approximately $13.5 million has been spent on the research and technology development work described in the response to Question #1. There is currently no planned FY 2020 funding for continuation of this research or application of this capability. The research and development effort for the IRAS has matured the technology to the point where other NASA programs/projects may choose to infuse the new technology.

Question 1b:

Is NASA partnering with other federal agencies or Departments?

Answer 1b:

Yes, NASA cooperates and has ongoing partnering activities with the departments of Energy, Defense, and Transportation (DOE, DOD, and DOT). NASA also participates on the Inter-Agency Power working group (IAPG) where information on research activities is exchanged on a quarterly basis. Research coordination is most active with the U.S. Army, DOE, and the U.S. Navy.

Question 2:

What NASA investments are being made in hydrogen technologies as it relates to generation, distribution, compression or storage to meet NASA's mission needs and requirements?

Answer 2:

NASA continues to conduct research on cryogenic transfer of propellants and feasibility studies for utilizing terrestrial electrochemical technologies in space applications. In addition, NASA is conducting ongoing development and demonstration of technologies to enable cryogenic liquefaction and storage of hydrogen; electrochemical generation and consumption of hydrogen using electrolyzers, fuel cells and regenerative fuel cells for terrestrial, aeronautic, and space applications.

For example, NASA's Evolvable Cryogenics and CryoFluid Management projects are developing, validating, and integrating cryogenic fluid management technologies at a scale relevant for possible infusion into a variety of future space vehicles and space systems, including future missions to the lunar surface.

Because cryogenic propellants need to be stored at ultra-low temperatures, handling and storing propellants such as hydrogen can be difficult. Energy, in the form of solar radiation and heat conducted by the rocket structure itself, continuously threaten to raise fuel temperatures, causing the fluid to evaporate, or "boil off," making it unusable as a propellant. Current technologies seek to rid the fluids of this persistent threat, keeping them cold by boiling or evaporating away the heat energy. These projects are developing additional solutions for in-space storage and transfer of cryogenic propellants that are more efficient when it comes to energy use, cost, and mass, which could benefit a range of extended science and exploration missions throughout the solar system. For example, the eCryo project will begin its Structural Heat Intercept-Insulation-Vibration Evaluation Rig (SHIIVER) testing in July 2019 to demonstrate the effectiveness of new multi-layer insulation, and evaluate the potential benefit of using vapor vented from a propellant tank to intercept heat coming into the tank through structural elements. Both of these efforts will allow the Agency to use hydrogen more efficiently.

Question 3:

Commercial and retail users have expressed concerns about reliability with hydrogen supply. For example, there are instances in California where retail hydrogen stations have, sporadically, not had adequate supply to fuel cell electric vehicles. Is NASA experiencing any hydrogen supply reliability issues? If so, what impacts are the hydrogen supply issues having on NASA's programs and plans?

Answer 3:

NASA contracted liquid hydrogen supply has been reliable. During 2018, NASA's hydrogen suppliers began stating the market had tightened, but the only impacts to NASA have been to provide advance notice and to coordinate schedules and provide some coordination and deconflicting between Centers. This is typically during periods of high launch related demand at KSC in the same timeframe as high engine-testing demand at SSC.

Question 4:

Hydrogen is transitioning from primary use as a commercial/industrial gas to a transportation fuel and as an energy storage medium. How is NASA preparing for this transition as increasing hydrogen demand from the commercial/retail sector grows exponentially?

Answer 4:

Demand growth is expected but it is unlikely to be exponential. Hydrogen suppliers have announced construction of three new liquid hydrogen production plants that are expected to begin supplying product in 2021. NASA expects supplier production capacity to be sufficient to continue to obtain reliable supply in the future.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:

Administrator Bridenstine

Submitted by Congresswoman Wexton

Question 1:

When discussing the cuts to the NASA Office of STEM Engagement, Administrator Bridenstine repeatedly justified the cuts due to NASA choosing to focus on "areas that have higher return for agency and the country."
What specific factors went in to the Administrator's determination to reduce the funding to $0 for the NASA Office of STEM Engagement? Did the Administrator consult with any outside groups or organizations? If so, who?

Answer 1:

NASA has a long history of engaging students in its mission through effective Science, Technology, Engineering, and Math (STEM) engagement activities and programs. NASA's endeavors in STEM engagement began early on, driven by the language in Section 203 (a) (3) of the Space Act which directs NASA "to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof, and to enhance public understanding of, and participation in, the Nation's space program in accordance with the NASA Strategic Plan."

While the FY 2020 budget proposes to eliminate the Office of STEM Engagement (OSE), it is important to understand that STEM education and outreach efforts have always occurred beyond the walls of the Education Office. These include internships managed by our Mission Directorates, our Speaker's Bureau which sends NASA scientists and engineers to meet with educational and civic organizations, and NASA employees who are authorized to use work hours to mentor local students in STEM activities. These are just a few of the STEM activities that NASA employees across the Agency proactively engage on every day. Therefore, even if OSE is eliminated, NASA's mission successes will continue to inspire the next generation to pursue science, technology, engineering, and mathematics studies, join us on our journey of discovery, and become the diverse workforce we will need for tomorrow's critical aerospace careers. We will use every opportunity to engage learners in our work and to encourage educators, students, and the public to continue making their own discoveries.

Following the elimination of OSE, NASA would staff a small, focused functional office at NASA Headquarters to be accountable for the strategic direction and coordination of the cross-Agency STEM engagement efforts, including more closely aligning Agency STEM efforts with our Mission Directorates and their missions. This would serve to better inspire students by having them work on real-world missions and problems, which in turn directly impacts NASA missions.

Fully recognizing the importance of its STEM mission, NASA has spent the last two years analyzing ways to optimize Agency STEM efforts as a whole. For example, NASA recently completed a deep-dive assessment of the Agency's Education and Outreach efforts, known as a Business Services Assessment (BSA). During this assessment, a core team collected data from across NASA, conducted surveys and interviews with internal and external stakeholders, benchmarked external organizations, and performed a detailed assessment of existing Education and outreach efforts. Based on this analysis, NASA created a more seamless approach to eliminate redundant functions and duplication of efforts, and fill in existing gaps in order to better serve the STEM engagement community. It also established the STEM Engagement Council (SEC), which is the Agency's governance body accountable for NASA's comprehensive set of STEM engagement functions and activities. Building on the BSA work, OSE is currently undergoing a Mission Support Future Architecture Program (MAP) Project to realign the mission support structures to improve efficiency in order to implement an integrated STEM function with a unified approach that will provide a higher return for NASA missions and the Nation's future STEM workforce.

As further proof of NASA's dedication to STEM outreach, it is important to note that NASA Administrator Bridenstine recently established the NASA Advisory Council STEM Engagement Committee in order to provide external advice and make recommendations regarding NASA's important role of inspiring the next generation. Committee Members represent external STEM stakeholders such U.S. universities and museums and industry associations. NASA is also actively supporting the National Science and Technology Council's Committee on STEM Education endeavors, with Administrator Bridenstine serving as the Committee's Co-Chair. The Committee's recent report, *Charting a Course for Success: America's Strategy for STEM Education*, lays out the federal Government's role in furthering STEM education by working with state, local, education, and American employer stakeholders to build a STEM-proficient citizenry, create a STEM-ready workforce, and remove barriers to STEM careers, especially for women and underrepresented groups.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:

Administrator Bridenstine

Submitted by Congresswoman Herrera Beutler

Question 1:

Last year's budget request stated that NASA's Office of Education lacked outcome- related data to demonstrate the effectiveness of its programs. NASA is once again proposing the cancellation of this program. Does NASA have a clearer understanding of the effectiveness of its education-related programs within the mission directorates?

Answer 1:

NASA has spent the last two years analyzing ways to optimize Agency Science, Technology, Engineering and Mathematics (STEM) efforts as a whole. For example, NASA recently completed a deep-dive assessment of the Agency's Education and Outreach efforts, known as a Business Services Assessment (BSA). During this assessment, a core team collected data from across NASA, conducted surveys and interviews with internal and external stakeholders, benchmarked external organizations and performed a detailed assessment of existing Education and outreach efforts. Based on this analysis, NASA created a more seamless approach to eliminate redundant functions and duplication of efforts, and fill in existing gaps in order to better serve the STEM engagement community. It also established the STEM Engagement Council (SEC), which is the Agency's governance body accountable for NASA's comprehensive set of STEM engagement functions and activities. Building on the BSA work, the Office of STEM Engagement (OSE) is currently undergoing a Mission Support Future Architecture Program (MAP) Project to realign the mission support structures to improve efficiency in order to implement an integrated STEM function with a unified approach that will provide a higher return for NASA missions and the Nation's future STEM workforce.

As further proof of NASA's dedication to STEM outreach, NASA Administrator Bridenstine recently established the NASA Advisory Council STEM Engagement Committee in order to provide consensus advice and make recommendations regarding NASA's important role of inspiring the next generation and having it be recognized by the whole of Government. Committee Members represent external STEM stakeholders such as U.S. universities and museums and industry associations. NASA is also actively supporting the National Science and Technology Council's Committee on STEM Education endeavors, with Administrator Bridenstine serving as the Committee's Co-Chair. The Committee's recent report, *Charting a Course for Success: America's Strategy for STEM Education*, lays out the federal Government's role in furthering STEM education by working with state, local, education, and American employer stakeholders to build a STEM-proficient citizenry, create a STEM-ready workforce and remove barriers to STEM careers, especially for women and underrepresented groups.

Most of NASA's current data regarding its STEM outreach efforts focuses on outputs of its education activities (e.g., number of students and educators reached). NASA will continue to monitor its efforts to share the STEM message with diverse groups, including women and individuals from underrepresented and underserved groups, pledging to use these results as a stepping stone for improved and expanded STEM outreach efforts. To this end, NASA is working on capturing improved demographics, while recognizing that demographics identification at NASA events is voluntary. Additionally, NASA will continue to engage the public and other key stakeholders in its activities, and work to build an open, transparent and participatory organization. Through strategic use of NASA assets in its STEM education offerings, NASA will share its inspirational activities with a broader audience.

It is important to understand that NASA's STEM education and outreach efforts have always occurred beyond the walls of the Education Office (e.g., internships managed by our Mission Directorates, our Speaker's Bureau which sends NASA scientists and engineers to meet with educational and civic organizations, and NASA employees who are authorized to use work hours to mentor local students in STEM activities). And these are just a few of the STEM activities that NASA employees across the Agency proactively engage on every day. Therefore, even if NASA's Office of STEM Engagement is eliminated, NASA's mission successes will continue to inspire the next generation to pursue science, technology, engineering, and mathematics studies, join us on our journey of discovery, and become the diverse workforce we will need for tomorrow's critical aerospace careers. We will use every opportunity to engage learners in our work and to encourage educators, students, and the public to continue making their own discoveries, while more closely aligning Agency STEM efforts with our Mission Directorates and their missions.

Question 2:

The INSPIRE Women Act showed Congress' continued support for NASA's initiatives to encourage young women and men to join careers in aerospace. How would the closing of the Office of Education influence theseprograms?

Answer 2:

NASA's overall portfolio of STEM/outreach activities will continue to provide opportunities to reach the demographic targeted by the INSPIRE Women Act[1]. Currently, a diverse set of events and activities is developed and sponsored by NASA

[1] It is important to note that NASA public engagement and education activities may not target a single gender, and thus, they are instead developed to reach both genders.

functional offices, Mission Directorates and their programs and projects, and by NASA Centers – all of which have the capacity to effectively inspire, engage and educate girls and young women in STEM. Going forward, NASA educational outreach activities will continue to leverage the Agency's unique mission of research and discovery as a powerful context for inspiration and student learning. Additionally, NASA will continue to work toward attracting and retaining diverse employees in STEM career fields while also providing student access to NASA's world-class research and technology facilities, mission data and Agency technical experts.

Specifically, The INSPIRE Women Act (P.L. 115-7) directed NASA to encourage women and girls to study STEM and to pursue STEM careers. NASA's efforts in this area span across the scope of NASA's endeavors in public engagement and education, with a focus on mentorship and opportunities that provide all students, including young women and girls with experiences interacting with NASA's women in action. NASA endeavors to provide unique opportunities for K-12, undergraduate and graduate students to be exposed to STEM through a spectrum of engagement. Activities that reach the targeted demographic, while fulfilling a broader purpose, include:

- NASA astronaut appearances,
- Speakers Bureau, Girls & Boys mentoring opportunities,
- Aspire to Inspire website, and
- Summer Institute in Science, Technology, Engineering and Research.

The spectrum of NASA's activities provides excellent opportunities to reach young women and girls. NASA will pull from various knowledgeable resources within the Agency to help expand the plan for future engagement.

For more information about how NASA is implementing the goals of P.L. 115-7, please refer to a report NASA provided to the Committee in July 2017, entitled: NASA Response to the INSPIRE Women Act (P.L. 115-7).

Question 3:

This FY 2020 budget request for NASA is $21.019B. The Obama Administration's last budget request (FY 2017) planned to request $19.879B in FY 2020. How does the additional $1.14B requested this year enable exploration, science, and aeronautics?

Answer 3:

The increase of $2.7B (including the budget amendment) primarily supports NASA's mandate to land the first American woman and next American man at the South Pole of the Moon by 2024, followed by a sustained presence on and around the Moon by 2028. The FY 2020 President's Budget submit increases the Human Exploration and Operations Budget in the Advanced Cislunar and Surface Capabilities Program, the Gateway Program, the Space Launch System Program and the Orion Program; all of which are critical to a 2024 human lunar landing. Additionally the request initiates a

Mars Sample Return mission and enables launch of the Europa Clipper mission in 2023. The FY 2020 Aeronautics funding level is relatively consistent with the direct portion of the FY 2017 President's Budget.

Question 4:

In 2013, this Committee heard testimony that 80 percent of NASA's infrastructure was beyond its constructed design life. Is this still the case? What can we do to ensure a key component of our nation's aerospace infrastructure does not fall into disrepair?

Answer 4:

NASA owns and manages a portfolio of facilities and real property with a total footprint of more than 500 square miles with a current replacement value of approximately $38B. Of that value, 80 percent is invested in constructed buildings and structures, predominantly technical in purpose and use. Likewise, as you note, 80 percent of NASA's facilities are more than 40 years, old and some have been in inventory for 80 years. Older facilities are more difficult and costlier to maintain, and are not designed to efficiently support the requirements of today's highly sensitive, technically evolved spacecraft and related hardware and systems. The advanced age of many of NASA's technical facilities also means that, despite ongoing maintenance, there is an intrinsic decline in quality and condition of the facilities, which creates risk to programs and projects that must be managed.

A challenge to managing NASA's highly technical programs is maintaining and modernizing facilities that were designed for an earlier age and purpose. NASA is addressing these challenges with infrastructure renewal policies that are founded on strategic facilities replacement goals for a gradual 25 percent Agency-wide reduction in facilities footprint over 20 years, as obsolete facilities are demolished and replaced with new, flexible-use, energy-efficient, sustainable structures. As these strategies are implemented, NASA continues to contend with the challenge of managing the demands of over $2.3B in deferred maintenance requirements. While NASA has made progress in holding steady the rate of increase through aggressive revitalization plans and demolition across its Centers, the ability to effect measurable reversal in the growth of these deferred requirements has remained elusive.

A well-functioning, efficient and cost-effective infrastructure is necessary for the support of NASA's mission requirements, and has a direct bearing on the level of risk to NASA mission objectives that must be managed. The availability of sufficient resources for NASA to meet these challenges of sustaining its infrastructure remains more critical than ever. NASA's FY 2020 budget request includes critical funding for construction and environmental projects to address these significant challenges. This funding will be important to enable NASA Centers to undertake actions that carry the Agency forward toward its infrastructure management objectives, including replacing obsolete capabilities with facilities that meet the demands of the missions of tomorrow.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Casten

Question 1-1a:

The FY 2020 budget request proposed canceling CLARREO Pathfinder. In response to a question by Representative Casten during the hearing, you said that "we have other instruments in orbit right now that are measuring the radiation budget of the Earth," referring to the types of measurements that CLARREO Pathfinder would enable.

As Representative Casten requested in the hearing, please provide a list of the specific operating or planned missions/instruments that would sufficiently meet the high-priority scientific objectives that an eventual CLARREO mission, enabled by the Pathfinder technology demonstration, would address.

Answer 1-1a:

CLARREO-Pathfinder is a one-year technology demonstration consisting of a reflected solar spectrometer instrument that would be flown on the International Space Station. It has two objectives:

1. Demonstrate the ability to conduct on-orbit calibration, to internationally-recognized measurement standards, with higher accuracy than is possible on current on-orbit Earth observing sensors; and
2. Demonstrate the ability to use that improved measurement accuracy to serve as an in-orbit reference for inter-calibration of other key satellite sensors across the reflected solar spectrum.

Several instruments set to operate in the timeframe of CLARREO-Pathfinder will obtain data on the Earth's radiation budget that are similar to those that would be collected by CLARREO-Pathfinder. However, they will do so with lower absolute accuracy than CLARREO-Pathfinder is being designed to achieve. The second objective is a unique feature of this mission, and will enable the transfer of CLARREO-Pathfinder's accuracy standards to other missions, in particular those with the Clouds and the Earth's Radiant Energy System (CERES) and Visible Infrared Imaging Radiometer Suite (VIIRS) instruments, on the Suomi-NPP and Joint Polar Satellite System missions. No current or planned instruments have the cross-calibration capabilities of the CLARREO-Pathfinder mission.

Question 1b:

As Representative Casten requested in the hearing, please "provide specifically who in the scientific community has confirmed that cutting those missions will not interfere with our ability to understand how our climate is changing [and] what we need to do to adapt."

Answer 1b:

We do not have knowledge of who made these specific comments. Several instruments set to operate in the timeframe of CLARREO-Pathfinder will obtain data on the Earth's radiation budget that are similar to those that would be collected by CLARREO-Pathfinder. However, the similar instruments will do so with lower absolute accuracy than CLARREO-Pathfinder is being designed to achieve. Additionally, the CLARREO-Pathfinder was designed as a one-year technology demonstration and was not intended to serve as a long-term climate mission.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Foster

Question 1-1a:

NASA has primarily powered its deep space probes with radioisotope thermoelectric generators (RTGs) using Pu-238. It has recently been increasing efforts to develop fission reactors, which can provide both propulsion and power. NASA is currently developing nuclear thermal propulsion systems using low-enriched uranium (LEU), and nuclear reactor power systems using highly-enriched uranium (HEU). If all the spacefaring nations start using HEU reactors, then it would involve the utilization of a significant amount of weapons-grade material.

Could the U.S. lead the way in developing space-qualified reactor power system designs using LEU?

Answer 1-1a:

Yes, there is considerable U.S. expertise to develop a range of space reactor options. NASA and the Department of Energy continue to study both highly-enriched uranium (HEU) and low-enriched uranium (LEU) fuel types for space power reactors. There are certain mass constrained missions for which HEU likely presents the optimum solution when considering all factors, including reactors in the 10 kW class (or less) that could serve robotic lunar landers and deep space science probes. In this class, the mass penalties for using LEU would likely negate the benefits of nuclear power since the landers and spacecraft that could use these fission power sources have significant payload capacity constraints. Current estimates indicate a 50 to 100% mass increase for a 10 kW LEU system versus a 10 kW HEU system, and the LEU option would require a new fuel system development compared to using existing capabilities. If mission power requirements reach above several 100 kW, the mass penalty for LEU can generally be accommodated without compromising mission objectives. The development of such a reactor would need to be supported by commensurate launch vehicle, lander, and spacecraft designs with sufficient payload capacity for the larger reactor systems.

Question 1b:

If the U.S. develops such a design, is it reasonable to believe it would be adopted as a de facto standard by other spacefaring nations?

Answer 1b:

Some other spacefaring nations, such as Russia and China, have their own space fission development plans which likely include HEU fuel options. Recent studies on space fission power sources by the European Commission, such as the Democritos Nuclear Electric Propulsion mission concept, indicated plans for partner country Russia to supply an HEU-fueled reactor. Few other nations have expressed interest in using a reactor for space exploration due to the cost and complexity. If interest is expressed by our international space partners, NASA could lead the way in developing a multi-mission LEU reactor option so long as U.S. International Traffic in Arms Regulations (ITAR) and Export Control policies can be maintained.

Question 1c:

Will NASA be devoting resources in FY 2020 to developing a LEU reactor for power and if so, how much?

Answer 1c:

NASA will continue to explore both HEU and LEU space reactors in FY 2020. Utilizing FY 2019 funds, NASA will continue NTP fuel development targeting a LEU-fuel solution. This includes complementary efforts under other NASA Programs such as Small Business Innovation Research (SBIR), Space Technology Research Grants (STRG), and Center Innovation Fund (CIF). Some of this research could be applicable to power reactors, and opportunities for cross-platform collaboration will be pursued.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

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

Question 1:

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

Answer 1:

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

Question 1a:

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

Answer 1a:

Please see response to Question #1, above.

Question 2:

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

Answer 2:

The Gateway program is in formulation, and the budget is based on initial cost estimates that are subject to further refinement as the program advances through the Agency life cycle review processes. With current operating plan adjustments for FY 2019 the Gateway budget is $332 million, and the amended President's Budget Request for FY 2020 would provide $500 million for the Gateway in FY 2020. The outyear estimates for Gateway are currently notional and will be further developed through the Agency life cycle review process and reflected in future budget requests. Additionally, our international partners are proceeding toward their respective stakeholders' approval and funding processes for evaluating whether to provide elements, modules, and capabilities for the exploration of the lunar surface, possibly through augmentation of the Gateway. NASA welcomed with enthusiasm Canada's announcement on February 28, 2019, that it would participate in lunar exploration by contributing advanced robotics to the Gateway, making the Canadian Space Agency the first partner agency to officially join NASA in the lunar exploration program. The Gateway is being designed to support sustainable missions to and operations on the surface.

Question 3:

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

Answer 3:

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

Question 3a:

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

Answer 3a:

The Orion program issued a Justification for Other than Full and Open Competition (JOFOC) for Production and Operations (P&O) beginning with Artemis 3 and issued a Request for Proposals (RFP) to the contractor in January 2018. The Orion program is currently in negotiations and expects the sole-source contract with Lockheed Martin to be in place in the summer of 2019. The Orion production and operations prime contract will enable production of Orion spacecraft starting with Artemis 3 and is structured to provide nominally six, and potentially up to 12, spacecraft builds. The contract features major emphasis on full reuse of the Crew Module, with refurbishment, as early as possible. The contract will enable the Artemis 3 Orion spacecraft to be available for flight in 2024. In addition, NASA signed an Implementing Arrangement with the European Space Agency (ESA) to provide service modules for the Orion spacecraft for Artemis 1 and Artemis 2. Orion is in discussions with ESA about their continued contribution of service modules for the Orion spacecraft for Artemis 3 and subsequent missions.

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

Question 3b:

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

Answer 3b:

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

Question 4-4a:

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

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

Answer 4-4a:

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

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

Question 4b:

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

Answer 4b:

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

Question 4c:

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

Answer 4c:

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

Question 5-5a:

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

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

Answer 5-5a:

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

During the Green Run testing, engineers will install the core stage that will send Orion to the Moon in the B-2 Test Stand at NASA's Stennis Space Center near Bay St. Louis, Mississippi for a series of tests over several months. The term "green" refers to the new hardware that will work together to power the stage, and "run" refers to operating all the components together simultaneously for the first time. Many aspects will be carried out for the first time, such as fueling and pressurizing the stage, and the test series culminates with firing up all four RS-25 engines to demonstrate that the engines, tanks, fuel lines, valves, pressurization system, and software can all perform together just as they will on launch day.

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

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

Question 5b:

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

Answer 5b:

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

Question 6:

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

Answer 6:

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

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

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

Question 7:

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

Answer 7:

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

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

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

avenue for companies to pursue private astronaut missions.

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

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

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

Question 8:

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

Answer 8:

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

Question 9:

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

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

Answer 9:

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

Question 10:

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

Answer 10:

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

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

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

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

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

Question 11:

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

Answer 11:

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

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

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

Question 12:

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

Answer 12:

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

Question 13-13a:

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

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

Answer 13-13a:

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

Question 13b:

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

Answer 13b:

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

Question 14-14a:

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

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

Answer 14-14a:

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

Question 14b:

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

Answer 14b:

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

Question 15:

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

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

Answer 15:

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

JWST and WFIRST address questions about the formation and evolution of the universe in different ways. JWST studies smaller fields of view in unprecedented depth, including, for example, the earliest stars and galaxies and atmospheres of exoplanets. WFIRST studies large samples of galaxies at all epochs to better understand overall cosmic evolution and understand how our universe came to be, and can use its wide field of view to discover rare objects.

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

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:

Administrator Bridenstine

Submitted by Congresswoman Sherrill

Question 1-1a:

The FY 2020 budget proposal would eliminate the NASA Office of STEM Engagement. The Office of STEM Engagement provides funding for eighteen institutions in New Jersey and over ninety-percent of award recipients have continued to graduate study or employment in STEM . You testified during the hearing that NASA supports other education initiatives through the mission directorates.

Please provide an accounting of the support for STEM initiatives in each of the other mission directorates.

Answer 1-1a:

NASA has a long history of engaging students in its mission through effective Science, Technology, Engineering, and Math (STEM) engagement activities and programs. NASA's endeavors in STEM engagement began early on, driven by the language in Section 203 (a) (3) of the Space Act which directs NASA "to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof, and to enhance public understanding of, and participation in, the Nation's space program in accordance with the NASA Strategic Plan."

While the FY 2020 budget proposes to eliminate the Office of STEM Engagement (OSE), it is important to understand that STEM education and outreach efforts have always occurred beyond the walls of the Education Office (e.g., internships and fellowships managed by our Mission Directorates, our Speaker's Bureau which sends NASA scientists and engineers to meet with educational and civic organizations, and NASA employees who are authorized to use work hours to mentor local students in STEM activities). Therefore, even if OSE is eliminated, NASA's mission successes will continue to inspire the next generation to pursue science, technology, engineering, and mathematics studies, join us on our journey of discovery, and become the diverse workforce we will need for tomorrow's critical aerospace careers. We will use every opportunity to engage learners in our work and to encourage educators, students, and the public to continue making their own discoveries. (Please see the attached spreadsheet for examples of STEM work managed by NASA's Mission Directorates.)

Following the elimination of OSE, NASA would staff a small, focused functional office at NASA Headquarters to be accountable for the strategic direction and coordination of the cross-Agency STEM engagement efforts, including more closely aligning Agency STEM efforts with our Mission Directorates and their missions. This would serve to better inspire students by having them work on real-world missions and problems, which in turn directly impacts NASA missions.

Fully recognizing the importance of its STEM mission, NASA has spent the last two years analyzing ways to optimize Agency STEM efforts as a whole. For example, NASA recently completed a deep-dive assessment of the Agency's Education and Outreach efforts, known as a Business Services Assessment (BSA). During this assessment, a core team collected data from across NASA, conducted surveys and interviews with internal and external stakeholders, benchmarked external organizations and performed a detailed assessment of existing Education and outreach efforts. Based on this analysis, NASA created a more seamless approach to eliminate redundant functions and duplication of efforts, and fill in existing gaps in order to better serve the STEM engagement community. It also established the STEM Engagement Council (SEC), which is the Agency's governance body accountable for NASA's comprehensive set of STEM engagement functions and activities. Building on the BSA work, OSE is currently undergoing a Mission Support Future Architecture Program (MAP) Project to realign the mission support structures to improve efficiency in order to implement an integrated STEM function with a unified approach that will provide a higher return for NASA missions and the Nation's future STEM workforce.

As further proof of NASA's dedication to STEM outreach, it is important to note that NASA Administrator Bridenstine recently established the NASA Advisory Council STEM Engagement Committee in order to provide consensus advice and make recommendations regarding NASA's important role of inspiring the next generation and having it be recognized by the whole of Government. Committee Members represent external STEM stakeholders such U.S. universities and museums and industry associations. NASA is also actively supporting the National Science and Technology Council's Committee on STEM Education endeavors, with NASA Administrator Bridenstine serving as the Committee's Co-Chair. The Committee's recent report, *Charting a Course for Success: America's Strategy for STEM Education*, lays out the federal Government's role in furthering STEM education by working with state, local, education, and American employer stakeholders to build a STEM-proficient citizenry, create a STEM-ready workforce and remove barriers to STEM careers, especially for women and underrepresented groups.

Question 1b:

What assessments of the NASA Office of STEM Engagement and education initiatives in the mission directorates have you completed to support the rationale for eliminating the Office of STEM Engagement?

Answer 1b:

Please see NASA's response to Question #1a.

Question 2-2a:

In New Jersey 28 percent of our awards go to minority and 43 percent go to female students. As this program positively impacts a diverse and broad reaching community of students:

Are any of the other education initiatives in the mission directorates specifically targeted to underrepresented and/or underserved communities?

Answer 2-2a:

NASA STEM activities both disseminate knowledge of the Agency's advances in science, technology, aeronautics and space exploration, and support the creation of knowledge by learners, educators, and institutions. NASA Offices, Mission Directorates, Centers, and Facilities collaborate to implement a single Agency-wide approach to STEM education. This approach provides unique NASA experiences to learners, educators, and institutions, as well as streamlined access to NASA content, websites, people, resources, and facilities.

Building a strong STEM workforce for the 21st century and beyond requires the development of a stronger and more diverse pipeline for STEM, including women and individuals from other underrepresented and underserved groups. To maintain a globally competitive Nation, our education programs develop and deliver activities that support the growth of NASA's and the Nation's STEM workforce, help develop STEM educators, engage and establish partnerships with institutions, and inspire and educate the public.

Most of NASA's current data regarding its STEM outreach efforts focuses on outputs of its education activities (e.g., number of students and educators reached). NASA will continue to monitor its efforts to share the STEM message with diverse groups, including women and individuals from underrepresented and underserved groups, pledging to use these results as a stepping stone for improved and expanded STEM outreach efforts. To this end, NASA is working on capturing improved data on demographics, while recognizing that demographics identification at NASA events is voluntary. Additionally, NASA will continue to engage the public and other key stakeholders in its activities, and work to build an open, transparent and participatory organization. Through strategic use of NASA assets in its STEM education offerings, NASA will share its inspirational activities with a broader audience.

Question 2b:

Has NASA analyzed the demographics of the participants in the initiatives in the mission directorates and the Office of STEM Engagement programs?

Answer 2b:

Please see NASA's response to Question #2a.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Waltz

Question 1:

I have heard that NASA recently decided to qualify a new source of ammonium perchlorate for the first Space Launch System Flight Support Booster (FSB-1). Given that ammonium perchlorate is the largest propellant component of each SLS solid rocket booster, is this true, and is the new source foreign or domestic? Does NASA intend to use the new source in future launches? If so, has NASA analyzed what this will do to the existing domestic industrial base for ammonium perchlorate and solid rocket motors more broadly, including the effects on national security systems?

Answer 1:

As part of a multi-year affordability initiative, NASA has been investigating alternative sources of ammonium perchlorate (AP) because the price for the sole domestic source was rising to unacceptable levels. As part of that plan, we did purchase enough AP from a foreign source (at a much reduced price) to qualify that source with the Flight Support Booster (FSB-1) static motor test. NASA has maintained keen awareness of the industrial base issues related to solid rocket motor production and co-authors with the Department of Defense (DoD) a semi-annual report to Congress on the AP industrial base. NASA worked closely with the DoD, and they concurred that NASA's qualification of this second source does not harm U.S. national security interests. Since AP is the largest material component in the Booster propellant, NASA's goal is to have multiple sources available for AP such that market competition will keep the prices down. In fact, NASA is currently buying a significant amount of U.S.-sourced AP concurrent with qualification of the foreign-sourced AP. NASA's goal is to ensure that there is a continued source of AP for our uses, and will continue to monitor the health of the U.S. solid rocket motor industrial base in concert with the DoD and national security needs.

Question 2:

NASA uses what's called Enhanced Use Lease Authority with GSA at Kennedy Space Center (KSC). This authority allows excess property to be utilized by commercial entities and up to 65 percent of the lease proceeds can then be used on common use infrastructure projects at KSC. This leasing authority is set to expire, right when we need more investment at Kennedy to meet bold objectives, not less. Can you please speak to the importance of the Enhanced Use Lease agreement and its impact on crucial infrastructure at the KSC that benefits all spaceport users?

Answer 2:

NASA's Enhanced Use Leasing (EUL) authority allows all NASA Centers to enter into leases of underutilized non-excess Agency real property with private sector entities, academic institutions, and state and local governments. This authority does not require any involvement from the General Services Administration. Under its EUL authority, NASA may retain lease revenues, thereby positioning the Agency to reduce operating costs, incrementally improve facility conditions, and improve mission effectiveness. The retention of proceeds under EUL authority improves NASA's ability to address facility and maintenance issues in a timely way, thereby reducing the rate of increase of NASA's overall deferred maintenance, currently over $2.3 billion. Since tenants pay consideration at fair market value, NASA has realized net proceeds that have been used to make necessary repairs to infrastructure and to invest in energy savings projects which have helped to reduce utility costs. NASA considers its current EUL authority a valuable tool to aid in the preservation of unique, non-excess assets, rather than allowing them to fall into disrepair.

At the Kennedy Space Center (KSC), EUL authority has enabled leases with diverse partners including communications service providers, media and media support organizations, and solar facilities, as well as the State of Florida and commercial space industry partners. Late in 2018, using NASA's EUL authority, KSC executed new land leases with two major commercial partners SpaceX, and Blue Origin. Under these leases, the partners will use and occupy parcels of unutilized, undeveloped land that is a part of KSC's buffer zone for construction of facilities to support their respective spaceflight hardware and launch vehicle design and manufacturing operations. Also late in 2018, KSC used NASA's EUL authority to enable Florida Power and Light to construct a 470-acre solar power facility. At KSC, EUL revenue proceeds have enabled energy and sustainability upgrades to facilities and mechanical repairs and system upgrades, such as oxygen system upgrades. These facility and infrastructure maintenance, capital revitalization, and improvements enhance the delivery of required services not only to NASA's facilities at KSC, but also to KSC's spaceport partners, particularly those engaged in commercial aerospace activities. KSC continues to seek opportunities for EUL partnerships that are compatible with NASA's mission and support appropriate and responsible management of its real property.

NASA's current EUL authority will expire on December 31, 2019. The loss of EUL authority, would cause an increase in underutilized and/or vacant NASA facilities requiring ongoing maintenance to prevent them from deteriorating. Over time, a continuation of NASA's EUL authority on an annual renewal basis, though certainly preferable to an outright loss of the authority, will create a level of uncertainty regarding its use as a strategic facilities planning tool. NASA's potential partners often are seeking longer-term lease arrangements for the stability of their operations and the prospects for reasonable return on reutilization development investments.

Uncertainty about the possibility of future renewals or extensions may have a chilling effect on the ability of NASA centers to attract the type of compatible business and partnership activities that have contributed to successful revitalization efforts such as those at KSC in recent years. As such, a longer-term EUL authority would provide a more stable, reliable framework for NASA to undertake out-lease decisions going forward.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Babin

General

Question 1:

The NASA IG recently issued a report on NASA's cleanup efforts at the Santa Susana Field Laboratory. The IG questioned "the reasonableness and feasibility of the Agency's current agreement to clean the soil to a Background level." The IG stated, "This cleanup approach is not based on risks to human health and the environment or the expected future use of the land-the standard practice for environmental remediation at similar sites. Further, a soil cleanup to the current levels set by the State of California is expected to cost NASA more than a half billion dollars, take as long as 25 years to complete, and significantly damage flora and fauna at the site. In contrast, soil cleanup to the Recreational level-the standard more in line with the expected future use of the land-would cost about $124M and take approximately 4 years to complete. As such, we question a total of $377M in unfunded environmental liability costs associated with NASA's current SSFL soil cleanup plans as funds that could be put to better use." Is NASA still pursuing a plan that is likely not achievable, would cost more money, take more time, result in no appreciable environmental benefit, and potentially be harmful to animals and plants currently at the site?

Answer 1:

NASA concurred with the recommendations of the March 19, 2019, report of the NASA Office of Inspector General (OIG) on NASA's Progress in Environmental Remediation Activities at the Santa Susana Field Laboratory (SSFL). The OIG recommended that NASA pursue all available options for ensuring a soil cleanup that is "performed in an environmentally and financially responsible manner based on the future use of the property."

In 2017, the California Department of Toxic Substances Control (DTSC) released a draft Programmatic Environmental Impact Report (PEIR) that described significant and unavoidable impacts associated with soil cleanup at SSFL. The cleanup outlined in DTSC's draft PEIR requires substantially greater soil removal than original estimates and would pose significant environmental impacts to the site's valuable and protected natural, cultural and biological resources. NASA has expressed these concerns to DTSC.

NASA entered into the 2010 Agreement on Consent (AOC) with the California DTSC in good faith, with the expectation that the State would use sound regulatory discretion in calculating soil cleanup levels for the site that would be both fully protective of public health, and practically and technically achievable. NASA encourages the DTSC to reconsider the limited alternatives included in its PEIR and expand its analysis and evaluation of clean-up actions to include options that would be less harmful to the site, preserve its unique resources, and still fully protect public health.

On April 5, 2019, NASA announced its decision to prepare a Supplemental Environmental Impact Statement (SEIS) for soil cleanup at the NASA portion of SSFL. Due to significant changes in soil cleanup estimates since NASA's 2014 EIS, as well as additional new data provided by the best science and technology available, NASA has determined that the SEIS is necessary in order to maintain compliance with the National Environmental Policy Act of 1970. From this further examination, NASA will assess updated soil and environmental data to refine and inform decision-makers, the regulating agencies, and the public about the likely environmental impacts that the cleanup will have on the community as well as the natural, cultural and biological resources at SSFL.

NASA remains firmly committed to a cleanup that is fully protective of public health and the environment. The Agency will continue to work with the DTSC and all interested stakeholders to implement a cleanup that is technically achievable, based on the best available science, protective of the surrounding community and the important natural and cultural resources at SSFL.

Human Exploration and Operations

Question 2:

What kind of capabilities will the Lunar Gateway demonstrate? How will those new capabilities enable expansion of human and robotic presence throughout the solar system?

Answer 2:

The lunar Gateway is being designed to support the return of American astronauts to the surface of the Moon. The architecture to enable the Exploration Campaign and support a human landing on the Moon in 2024 (which includes the Gateway as well as the Orion crew vehicle and Space Launch System [SLS]) is the same architecture already in development to support our previous goal to land on the Moon in 2028.

The Gateway will be a spacecraft assembled in cislunar space that will be used as a staging point for missions to the lunar surface and to future deep space destinations. The Gateway will function as a mobile base camp from which NASA, its international partners, and its commercial partners, can mount sustainable robotic and human expeditions to and around the Moon. Our initial focus must be on speed, but long-term sustainability and broader partnerships will be required to support our ultimate goal: human missions to Mars.

NASA and its partners will develop and deploy the Gateway's two initial components: the Power and Propulsion Element (PPE) that will launch in 2022 as a public-private partnership, and a minimum Habitation capability that will launch in 2023. Both of these modules will be launched on commercial launch vehicles. This initial Gateway configuration can support the first, short-duration missions to the lunar surface. For the 2024 mission, Gateway will serve as the staging point for the three elements of the human lunar landing system (a transfer vehicle, descent vehicle, and ascent vehicle) launched by commercial vehicles, and the crew that will arrive on Orion.

NASA will build on the 2024 mission to ensure that access to the Moon and its resources is sustainable over the long haul. This will require NASA to expand its capabilities with international and commercial partners with the goal of improving the sustainability and cost-effectiveness of lunar activities. The Gateway has several attributes that will contribute to long-term lunar exploration: it will be sustainable (e.g., through resupply and the ability to conduct long-duration human surface missions and extended uncrewed operations); reusable (unlike the Apollo Command/Service Module, Gateway will be on hand to support many lunar missions); and flexible (using its solar-electric PPE, Gateway will allow us to access more regions of the Moon than ever before). Gateway will be followed by other assets that would enable sustainability, such as reusable landers, reusable tugs, rovers, robotics, etc., allowing our astronauts to operate on the Moon for extended durations and to take advantage of the Moon as an analogue for Mars. In a Near-Rectilinear Halo Orbit around the Moon, Gateway will support communications with the Earth, have the ability to abort from the surface of the Moon to the Gateway, and experience benign thermal effects. Gateway can also provide additional capabilities that could enable science utilization, exploration technology demonstrations, and potential commercial utilization. Ultimately, Gateway enables the demonstration of capabilities on and around the Moon (such as extended surface operations; high-power solar-electric propulsion systems; human health and life support systems technologies; radiation mitigations for both crews and hardware; and deep-space rendezvous, proximity operations, and navigation) that are required for human missions to Mars and other destinations.

Question 3:

How do multiple launches or multiple stages affect safety and risk postures for lunar landers?

Answer 3:

NASA is planning to maximize reusability in its deep space exploration systems, including human lunar landers, and will work to ensure the safety of the astronaut crews. NASA is soliciting lunar lander architecture through a Broad Agency Announcement (BAA) under its second Next Space Technologies for Exploration Partnerships (NextSTEP-2) effort. The NextSTEP-2 BAA is soliciting concepts from

U.S. industry in support of rapid development, integration, and crewed demonstration of the lander elements as a functional human landing system that can accelerate landing on the Moon in 2024.

These inputs, in turn, will inform NASA's plans that currently include a transfer vehicle ferrying a two-stage lunar lander from the Gateway to low lunar orbit, whereupon the lander would descend to the lunar surface. Under this notional plan, at the conclusion of the surface expedition, an ascent stage would carry the crew back to low lunar orbit, where they would rendezvous and dock with the transfer vehicle and proceed back to the Gateway. Both the transfer vehicle and ascent stage would be refueled at the Gateway and prepared for future lunar missions. This system would allow for mission aborts at various points during the lunar sortie using the transfer vehicle or the ascent stage of the lander. If required, the ascent stage could even return to the Gateway without the need to dock to the transfer vehicle.

The overall safety and risk posture of a mission as complex as a human lunar landing is dependent on a number of interrelated factors, starting with the overall design of the individual hardware elements (which are themselves highly complex systems), test and evaluation plans, the concept for how the systems will be operated, system and architectural redundancy and reliability, launch vehicle availability, mission abort and other contingency options (which change throughout the mission), astronaut and operator training, and a wide variety of other technical and operational factors. Increasing the number of architectural elements, such as adding multiple launches or stages, can introduce risks. On the other hand, devolving the lunar lander mission into a series of lander and transfer elements, each optimized for their specific function, aggregated at and staged out of a reusable Gateway platform, and leveraging reusability, creates significant opportunities for reducing risks and improving overall mission safety and success. Lunar lander elements can be tested and checked out *en route* to the Gateway. Astronauts arriving at Gateway in Orion can check out lunar lander systems at the Gateway before departure to the lunar surface. Staging lunar lander elements creates safe abort opportunities for the crews to return to Gateway if necessary. Reusability allows us to observe the reliability of systems over time, allowing for continuous improvement of the overall architecture and informing the design of the high-reliability systems needed for sustained missions at the Moon and in preparation for long-duration missions to Mars.

Question 4:

How long will the Lunar Gateway operate?

Answer 4:

The Gateway is being designed for an operational life of at least 15 years.

Question 5:

When will NASA issue a contract for the second Launch Platform that was funded last year? Does NASA need more money to complete this project? If so, how much more? Does this budget request assume funding to complete theproject?

Answer 5:

Consistent with provisions in the FY 2018 Consolidated Appropriations Act (P.L. 115-141), as well as the NASA Administrative Provision in P.L. 115-141 pertaining to the Agency's Operating Plan, NASA is proceeding with a contract award in 2019 to start building the second mobile launcher platform.

Although NASA began design and construction on the second mobile launcher platform, additional funding to complete the project is being deferred. NASA does not have plans to utilize the second mobile launcher in the near term and a final Block 1B design has not been set. NASA is deferring these activities until needed but allowing core design and construction of the platform to continue while awaiting a decision on the upper stage configuration for future missions.

Question 6:

Once the Commercial Crew program is fully underway, NASA will have the ability to add an additional crewmember to the International Space Station. How will this influence planning for ISS transition in the next decade? Could the ISS support more than seven crew?

Answer 6:

U.S. commercial crew capabilities will enable the Station crew to be expanded from six to seven astronauts and cosmonauts, resulting in a doubling of on-orbit research time to almost 80 hours per week. This is because the seventh crew member will be able to focus his or her time almost exclusively on conducting experiments, rather than on Station operations and maintenance. While Station has hosted up to 13 crew at a time during brief periods when the Space Shuttle was docked to the Station, it is important to note that the long-term crew complement is constrained by the number of seats available on the crew transport vehicles docked to ISS. Once commercial crew vehicles have become operational, the ISS could support four additional crew members for four weeks nominally beyond the seven ISS crew members. It is possible to either increase the number of crew members by a couple for a short period, or extend the duration of the four additional crew members with additional logistics.

Question 7:

Please discuss NASA's current thinking on commercialization and transition strategies for the ISS.

Answer 7:

NASA's current thinking on commercialization and transition strategies is covered in the International Space Station Transition Report directed in the NASA Transition Authorization Act of 2017 (P.L. 115-10) and delivered to Congress in March 2018. The report may be accessed via the link below:

https://www.nasa.gov/sites/default/files/atoms/files/iss_transition_report_180330.pdf

Question 8:

If NASA is unable to reduce its costs for operations and transportation to the ISS by 2025, and if the LEO commercialization activity does not bear fruit, what should the US do regarding its presence on the ISS at that point? Should we defer Lunar exploration to maintain a presence in low Earth orbit? If so, for how long?

Answer 8:

ISS is a critical component of the National Space Exploration Campaign, and NASA will continue its mission in LEO with the ISS to enable exploration with humans to the Moon and on to Mars, continuing to perform research that benefits humanity, supporting National Lab research by private industry and other organizations, and working towards reducing operations and maintenance costs. The Commercial LEO Development effort is providing resources for NASA to assist industry in developing a commercial LEO presence, with and without crews. As those commercial LEO destinations are available, and without a gap in human presence in LEO, NASA intends to implement an orderly transition from current ISS operations to the new commercial enterprise as laid out in NASA's ISS Transition Report. NASA has also identified its long-term requirements for LEO operations and research that is planned to be conducted on the ISS and transitioned to a commercially operated platform(s). NASA has every reason to believe that both its Commercial LEO Development and lunar exploration efforts will be successful, and is not currently evaluating any trades specifically between these two lines of effort.

Question 9:

We are starting to see an increasing convergence between human space exploration and the planetary science activities carried out under the Science Mission Directorate. Could you please talk a bit about this convergence and how the two lines of effort can be more effectively coordinated?

Answer 9:

The convergence between human spaceflight exploration and planetary science activities is deliberate. The two share common goals and objectives in exploring the Moon and Mars. Finding and establishing ground truth of volatiles, such as water-ice, is an example of this. Water-ice may provide the critical resource needed to sustain human life on the surface of the Moon, while also providing fuel for future rockets and landers. Determining the distribution of the water-ice in the permanently shadowed regions also aligns with Decadal Survey science objectives.

To ensure the close coordination between the human spaceflight exploration and science objectives, and proper alignment of technology development efforts to support both, NASA established an Office for Exploration in the Science Mission Directorate that is led by a new Deputy Associate Administrator (DAA) for Exploration. The responsibility of the DAA for Exploration is to ensure and facilitate the integration of the human exploration, science, and technology development efforts to better support and enable the Agency's Exploration Campaign objectives. Since the establishment of the DAA for Exploration, there have been ongoing integrations efforts with senior leadership in the Human Exploration and Operations Mission Directorate (HEOMD) and the Space Technology Mission Directorate (STMD). Examples of successful integration efforts include the consolidated exploration budget request in the FY 2020 President's Budget Request, the ongoing participation of the three mission directorates in dialogue related to the Gateway platform, and robotic and human lunar surface exploration goals and objectives.

As the critical elements of NASA's Exploration Campaign continue to mature, undergo development and are deployed, the integration between the HEOMD, SMD and STMD will continue to evolve as needed to ensure close coordination and integration.

Question 10:

Congress has consistently appropriated more funding than requested in the Presidential Budget Requests each year for the past six years to ensure Orion remains on schedule. Congress has maintained its support for keeping Orion on schedule. In the FY 2020 PBR, NASA once again requested less than FY 2019 appropriations. Will a decrease in funds still maintain the current Exploration Mission I and 2 schedules?

Answer 10:

The FY 2020 Budget, as amended, requests $1,406.7 million for Orion, $56.7 million above the FY 2019 level. NASA is committed to flying Artemis 1 and Artemis 2 in order to ensure the safe landing of a crew (including the first woman) on the Moon by 2024. This focus is reflected in the Agency's amended FY 2020 budget submit to Congress.

Question 11:

What is NASA's plan for ISS operations after 2024? How will this impact Deep Space Exploration efforts, assuming that NASA only sees flat or moderate increases in future budgets?

Answer 11:

NASA will continue research and technology efforts in low-Earth orbit (LEO) using the International Space Station (ISS) to enable exploration with humans to the Moon and on to Mars. NASA is working to implement a step-wise transition of ISS from the current regime of NASA sponsorship and direct NASA funding, to a regime where NASA is one of many customers purchasing services from a LEO non-Governmental human space flight enterprise. NASA will gradually transition from current ISS operations to this new regime to ensure that the United States always has access to a crewed space station in LEO. As part of this transition, NASA plans to purchase needed LEO services from a commercial operator of ISS and/or new commercial LEO destinations. The full transition from ISS to new commercial LEO destinations will be gradual.

Over the next several years, the research program will continue to focus on capabilities needed to maintain a healthy and productive crew in deep space. Manifested or planned experiments and demonstrations to enable human exploration at the Gateway, lunar surface and into deep space include tests of improved long-duration life support, advanced fire safety equipment, on-board environmental monitors, techniques to improve logistics efficiency, in-space additive manufacturing, advanced exercise and medical equipment, radiation monitoring and shielding, human-robotic operations, and autonomous crew operations.

Science

Question 12:

This budget request for science is $677M more than what the Obama Administration planned for FY 2020 in its FY 2017 request. How does this increase in science funding enable future scientific discoveries?
Answer 12:

Compared to the notional out-years of the FY 2017 request, the FY 2020 request includes increases to Planetary Science programs and projects, including:

- the Lunar Discovery and Exploration Program
- Europa Clipper
- the Planetary Defense program and its Double Asteroid Redirection Test (DART) mission
- the competed Discovery and New Frontiers programs
- planning for a Mars Sample Return mission

These increases address priorities of the most recent National Academies Decadal Survey for Planetary Science. The Lunar Discovery and Exploration Program is also critical for returning humans to the Moon by 2024.

Question 13:

NASA has historically developed first-of-a-kind earth science instruments that, once proven, are transferred to operational agencies like NOAA or USGS. This budget requests seems to depart from that long-standing philosophy by funding the procurement of long-term data-sets that were previously NOAA requirements. It also funds missions not recommended by the decadal survey, instruments that collect data similar to existing international or other agency missions, and a mission that was criticized by the NASA IG as being unnecessary. How does NASA plan to prevent these legacy missions from delaying or inhibiting the development of next generation technologies?

Answer 13:

The scope and content of the FY 2020 budget request is consistent with previous requests. It does not include any new Earth Science missions or projects, except those that are recommended by the 2007 or 2017 Earth Science and Applications from Space Decadal Surveys or selected through competitive solicitations (e.g., Earth Venture missions).

The 2017 Decadal Survey states that NASA should implement the current Program of Record, which refers to the missions already in development that are largely based on the recommendations from the 2007 Decadal Survey. Completion of the Program of Record is a fundamental assumption of the 2017 Decadal Survey; for example, the 2017 Decadal Survey stated:

> *Recommendation 3.2: NASA should implement a set of space-based observation capabilities based on this report's proposed program (which was designed to be affordable, comprehensive, robust, and balanced) by implementing its portion of the Program of Record and adding observations described in Table 3.3, "Observing System Priorities."*

Completing the current Program of Record by 2023 is an essential foundation to allow NASA to proceed with the development of the next generation of Earth Science projects.

Question 14:

In 2005, the Near-Earth Object Survey program was created to detect near-Earth objects (NEOs) greater than 140 meters in diameter within 15 years (specified in law). NASA has only found about 43 percent of these NEOs. However, the space-based telescope Near-Earth Object Camera (NEOCam) mission, or a similar concept, could discover and characterize most of the potentially hazardous asteroids that are near the Earth. How does NASA propose funding the NEOCam mission in FY 2020? Has it been selected to proceed to mission formulation? If not, how is NASA planning to meet the survey requirement in law? Are there other spacecraft proposals that could accomplish the same goal?

Answer 14:

NASA Science Mission Directorate (SMD), through the Planetary Defense Program, has proposed to continue development of a space-based infrared instrument at approximately $36 million in the President's

FY 2020 budget request.

Current assets with the addition of the NSF's Large Synoptic Survey Telescope (LSST) in 2023 are projected to meet the George E. Brown survey goal of detecting 90 percent of NEOs greater than 140 meters in the 2040s. Additional assets (both ground- and space-based) would be required to significantly reduce the time necessary to detect and characterize NEOs greater than 140 meters in size.

Pursuant to Section 511 of the NASA Transition Authorization Act of 2017 (P.L. 115-10), NASA will continue to provide status reports to the Congress on NEO detection and characterization.

Question 15:

The President's FY 2020 budget request directs NASA to continue to utilize CubeSats and private sector remote sensing payloads. How can NASA leverage Earth Science funding more effectively? Is this kind of "commercial off the shelf' technology development important in NASA's overall mission?

Answer 15:

Investment in CubeSats technologies and leveraging commercial capabilities are indeed important to NASA. Through the In-Space Validation of Earth Science Technologies (InVEST) program, NASA's Earth Science Division continues to develop new CubeSat technologies both within NASA and in the non-governmental sector. CubeSats can now also be selected as science payloads under Earth Venture Instrument competitive solicitations. As a part of the Earth Venture Instrument program, NASA selected the CubeSat missions TROPICS and PREFIRE in 2016 and 2018, respectively.

NASA is also pursuing the hosting of payloads on commercial satellites. In September 2018, General Atomics was awarded a contract to host the Multi-Angle Imager for Aerosols (MAIA). This is the first hosted payload for NASA Earth Science.

NASA continues to explore commercial sector developments in remote sensing payloads, especially where measurements and data are complementary to meeting NASA's Earth Systems science and applications goals. In September 2018, NASA launched a pilot program to evaluate whether Earth science data from commercial small-satellite constellations could be utilized to augment observations from the Agency's fleet of orbiting Earth science missions. The Agency awarded sole-source contracts to acquire data products from three private sector organizations: DigitalGlobe, Planet, and Spire. Even in cases where commercial data are not initially suitable for science purposes, there can still be synergies for collaboration.

Question 16:

Mars 2020, our next flagship mission to Mars, will use technology from the Curiosity rover to mitigate cost and risk. An OIG report from last year noted that several new technologies were still facing high risks, and NASA recently indicated the program could breach its cost estimate. What is NASA doing to address these remaining risks? If NASA terminates some of the instruments, will the mission still be able to generate new and novel scientific data?

Answer 16:

At this time, the Mars 2020 project has retired or mitigated all of the new technology risks identified by the recent OIG report. For example, the flight units for the sampling and caching robotic arms have been completed and delivered to JPL and components of the Adaptive Caching Assembly are being integrated and tested, such that the Sampling and Caching System (the main technology risk reported by the OIG) is on schedule for delivery by late summer. The MOXIE instrument has been completed and installed into the rover chassis. In addition, the MEDA instrument and SuperCam calibration target, which were noted as foreign partner contributions of concern, have been completed and delivered to JPL. Currently, no science instruments are being considered for termination, as all are on track for delivery in time for the spacecraft need dates.

Question 17:

When it comes to developing and conducting a mission like a Europa Clipper, does more funding mean faster development and launch? Or are there elements that cannot be sped up even with additional funding?

Answer 17:

The scientific and engineering elements of the Europa Clipper mission, designed to investigate whether this moon could be an abode for life, are complex and require the multi-faceted expertise of an extensive team, thus, the timetable is not solely dependent on funding or launch capabilities. Multiple elements of the project must be developed serially and therefore, cannot be sped up even with additional funding. Recent assessments by NASA and the Europa Clipper project team have concluded that a launch readiness date of 2023 is the most feasible option and the President's FY 2020 budget request supports such a schedule.

Question 18:

The budget proposal does not include funding for the Europa lander. Why was this program cancelled?

Answer 18:

The FY 2020 President's budget request for NASA does not include funds for a $3.5 – 5.0 billion Europa Lander due to support of higher Agency priorities. This is consistent with previous year budget requests. This also is consistent with the National Academies of Sciences, Engineering, and Medicine (NASEM) Planetary Science Decadal Survey midterm assessment that was the product of a committee of experts from the planetary science community. The midterm assessment recommended that the Europa Lander mission be assessed in the context of other planetary priorities in the next decadal survey.

Question 19:

The budget request proposes launching the Europa Clipper on a commercial launch vehicle, despite appropriations law that requires the mission be launched on an SLS to decrease the transit time and maximize the science conducted around Europa. How will the mission's science be impacted by this decision?

Answer 19:

NASA will follow the law regarding launch of the Europa Clipper mission. The FY 2020 President's budget request for NASA proposes to launch Europa Clipper in 2023 on a commercially-procured launch vehicle. Following an analysis of availability of launch hardware and facilities, overall launch manifest optimization, and cost, the Administration believes it would be more appropriate for the Europa Clipper to utilize a commercially-procured launch vehicle instead of a Space Launch System (SLS) variant. Science quality is not impacted by this decision. Delivery of scientific data to the planetary science community will be delayed, but is not in any way decreased, due to this trade-off involving cost.

Additionally, the Administration is concerned that the mandate to use an SLS rocket for the Clipper will slow the lunar exploration program, which requires every SLS rocket available. NASA does not believe that it can produce enough SLS rockets to do both Europa and the Artemis missions in the timeframe laid out. Unlike the human exploration program, which requires use of the SLS, the Europa mission could be launched by a commercial rocket.

Question 20:

The previous decadal survey for planetary science listed both the Europa mission and a Mars Sample Return mission as high priorities. In order to execute both at the same time, those concepts were scaled back to proposals that are more reasonable: the Europa Clipper and the Mars 2020 Rover. This budget request proposes a new Mars Sample Return Mission in addition to the Mars 2020 Rover. What impact will that have on other planetary missions, or the science division as a whole? What principles will inform the trades that NASA will make?

Answer 20:

The President's FY 2020 budget request proposes initiating a Mars Sample Return (MSR) mission – which is the next step towards accomplishing the goals outlined in the current decadal survey for planetary science, "Vision and Voyages for Planetary Science in the Decade 2013-2022 (2011)." The Mars 2020 mission fulfills the highest-priority large mission recommended by the decadal survey: a mission to select and cache samples of Martian rock and soil that begins a multiple-mission MSR campaign extending into the decade beyond 2022. The mission concept was reduced in cost and risk by descoping the proposed landed system from two rovers down to a single rover based upon the design of the successful Mars Science Laboratory (MSL). The resulting Mars 2020 rover will have significant scientific return in addition to being the first step in a sample return campaign. The requested budget also proposes initiating a cooperative partnership with the European Space Agency to conduct the campaign of sample retrieval missions, as envisioned by the Decadal Survey. This partnership will enable NASA to achieve the objectives of MSR at reduced cost and risk.

The Europa Clipper mission fulfills the decadal survey's second priority large mission. The cost was brought within budgeting constraints by streamlining the mission and changing the spacecraft's trajectory from an orbit around Europa to a series of flybys.

Through Congress' appropriations and NASA's innovation efforts, the decadal survey's first and second major mission priorities will both be accomplished. The MSR campaign fits within the proposed Mars Exploration Program budget and preserves the rest of the planetary portfolio and priorities of the Decadal Survey.

Question 21:

The recent Earth Science decadal review mentioned the value of CubeSats, smallsats, and hosted payloads. Given the proliferation of CubeSats and private sector remote sensing payloads, how can NASA leverage Earth Science funding more effectively? Is this kind of technology development important in NASA's overall mission?

Answer 21:

CubeSats, smallsats, and hosted payloads are indeed important to NASA, including the Earth Science Division (ESD). NASA's investments in and partnerships using these approaches have demonstrated the value of deploying small-scale, cost-efficient observing platforms to gather Earth observations from a greater variety of on-orbit sources. Because they draw heavily on commercial capabilities and partnerships, these technologies align with NASA's objective to advance our science and discovery through engagement with external partners.

Among the objectives of ESD's Earth System Science Pathfinder (ESSP) program is the pursuit of innovative approaches for addressing Earth science research by embracing small satellite projects and providing periodic opportunities to accommodate new and innovative techniques to address scientific priorities. For example, CYGNSS is an eight-satellite smallsat constellation that measures ocean surface winds at the core of tropical cyclones, and has been operational since 2016. This project is providing innovative science at a relatively low cost, demonstrating a new measurement technique for future science missions. In addition, ESD recently selected two CubeSat constellation projects - TROPICS and PREFIRE – from an Earth Venture Instrument (EVI) solicitation within ESSP in order to address science related to tropical cyclone thermodynamics and Arctic radiative energy, respectively. These low-cost missions seek to address important NASA science.

The Earth Science Technology Office (ESTO) invests in the development of new CubeSat technologies within NASA and in the non-governmental sector through the In-Space Validation of Earth Science Technologies (InVEST) program.

At the same time, NASA aims to promote and harness commercial remote sensing technology when commercial measurements could be complementary to NASA's science and applications goals. In September 2018, ESD launched a pilot program to evaluate how Earth science data from commercial small-satellite constellations could be utilized to augment observations from the Agency's fleet of orbiting Earth science missions. The Agency awarded sole-source contracts to acquire data products from three private sector organizations: DigitalGlobe, Planet, and Spire. Even in cases where commercial data are not initially suitable for science purposes, there can still be synergies for collaboration.

NASA is also pursuing the hosting of payloads on commercial satellites. In September 2018, General Atomics was awarded a contract to host the Multi-Angle Imager for Aerosols (MAIA), which will characterize the sizes, compositions, and quantities of different kinds of particulate matter in air pollution. This is the first hosted payload for NASA Earth Science, with a mission launch expected as early as the fourth quarter of 2021.

These multiple innovative approaches are important to ESD as they provide opportunities to address science priorities at costs lower than traditional satellite projects. While these approaches are not currently capable of fully addressing all of Earth Science's needs, they are making important contributions and are growing capabilities for the future.

Aeronautics

Question 22:

The FY 2020 budget requests to reallocate funding for aeronautics facilities from the Aeronautic Mission Directorate to the Safety, Security, and Mission Services Directorate. In doing so, it appears the budget requests a cut, but in reality, represents a healthy funding profile for Aeronautics. Can you discuss how moving this funding is better for NASA and the aeronautics enterprise?

Answer 22:

NASA's wind tunnels are unique national assets and the Agency is committed to maintaining, modernizing, and enhancing the Aeronautics Evaluation and Test Capability (AETC). Prior to FY 2017, AETC received a portion of its annual funding directly from the Aeronautics Research Mission Directorate. The rest was expected to be paid for by the users of the wind tunnels. Under this model, the ultimate funding total for AETC each year was unknown. Managers were forced to focus on how to cover their operating expenses for the year, and there was little investment made in enhancing or modernizing the capability. The funding profile increased in FY 2019 and again in FY 2020 to cover consumables (power, liquid nitrogen, etc.). The most consistent user of AETC is the ARMD, but projects in SMD, HEOMD, and STMD all utilize the capability from time to time. To acknowledge the benefits to the entire Agency, the FY 2017 Budget included direct funding in four appropriations accounts.

NASA executed the budget for AETC this way for FY 2017 and FY 2018. However, this model requires us to reconcile estimated funding allocated for AETC to each account with actual data. End-of-year transfers between appropriations ensure accurate accounting. Under the FY 2017 model, such transfers pose an administrative burden to Congress, AETC and the relevant NASA Centers. To reduce this burden and simplify an overly complicated accounting scheme, NASA made the decision to continue to provide the full annual AETC funding level, but to do so from a single source.

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

Question 23:

NASA is working with both tech companies and traditional aerospace firms on technology to enable a future where people and goods can be safely and efficiently transported around densely populated cities aboard air vehicles, called Urban Air Mobility. How is NASA collaborating with industry, academia and the Federal Aviation Administration (FAA) to identify and seek solutions to the challenges unique to this new era in aviation?

Answer 23:

Collaboration with FAA, industry and academia will be critical to the success of NASA's Urban Air Mobility research and development efforts. NASA Aeronautics has conducted research in the technology arenas of unmanned aircraft systems (UAS) and UAS traffic management (UTM) for the past decade, in close coordination with industry and the FAA. Many of the technical challenges addressed in this research will have direct applicability to future requirements and challenges of Urban Air Mobility (UAM) including vehicle technologies such as Detect and Avoid and secure command and control communications, as well as the UTM operational construct itself which is likely to be a critical enabler of a safe and scalable workable UAM system.

NASA is using many complementary venues to engage with the community on UAM. Starting in 2016, NASA conducted public workshops and sponsored market studies related to On Demand Mobility, building a community dialogue around UAM challenges and opportunities. NASA leadership and subject matter experts similarly engaged in discussions with FAA counterparts to identify community needs and FAA requirements that would inform NASA research. NASA Aeronautics reconstituted in 2018 the Aeronautics Research and Technology Roundtable (ARTR) under the auspices of the National Academies of Sciences with an enhanced focus on UAM as another important source of input from traditional and non-traditional industry members, academia and the FAA.

As a result of this broad community engagement, NASA is planning series of Grand Challenge demonstrations wherein industry will demonstrate vehicle and operational solutions for UAM ecosystem-wide, system level safety through increasingly more difficult integration scenarios. Participants will demonstrate practical and scalable system concepts while building a technical knowledge base used to inform and meet requirements and standards for both vehicles and air traffic management systems. NASA sponsored an Industry Day in late 2018 and issued a Request for Information to bring the stakeholder community together to solicit feedback on the Grand Challenge concept and assess industry interest in participation. Initial feedback has been positive, and NASA is refining plans based on the results.

Through the Grand Challenge and other engagements with the broader UAM ecosystem members, NASA will identify critical barriers to overcome through future R&D, vehicle and air traffic management system architecture, technologies, system integration and certification.

Question 24:

NASA's Aeronautics program works closely with industry to advance the state of the art in aviation technology. Which aviation technologies should NASA investigate in cooperation with industry for the national interest, and which technologies should industry be pursuing on its own?

Answer 24:

The critical challenge—and opportunity—facing the United States is to remain at the forefront of a growing and evolving aviation market. We must maintain leadership through technological superiority, and NASA Aeronautics has a unique and important role in that formula. NASA Aeronautics will continue its role of supporting a long-term vision for aviation and undertaking pre-competitive research and development that falls outside the scale, risk, and payback criteria that govern commercial investments. Engagement with industry during formulation and execution of NASA's research activities helps NASA to better understand industry priorities and capabilities, and supports the eventual transition of research results to the community. Once NASA explores and demonstrates the feasibility of these high risk, high payoff technologies and concepts, U.S. industry can then further mature them and transition them to commercial products. Companies also pay to use NASA ground and flight test infrastructure to validate their concepts and technologies, or to collaboratively explore new innovations for flight.

Similarly, NASA's research provides validated findings that inform the Federal Aviation Administration's (FAA) policy and rulemaking processes, industry standards, and global aviation standards and recommended practices. For example, NASA research into new air traffic management concepts and technologies directly transitions into FAA upgrades to the Nation's air traffic management system. NASA also conducts research into recognition and timely mitigation of safety issues as they emerge, before they become hazards or lead to accidents.

In terms of specific technology areas, NASA is conducting research in collaboration with industry to address the most critical long-term challenges facing aviation across six strategic research thrusts, focused on areas with the greatest community impact. NASA is building the quiet supersonic X-59 aircraft to collect community response data, enabling new rules to open up the market for overland commercial supersonic flight so companies can invest in developing and producing new aircraft for this market. NASA also is collaborating with U.S. industry to investigate innovative technology for subsonic aircraft such as advanced configurations and wing design, transformative structures, propulsion-airframe integration, and small-core turbine engines. NASA is conducting research to make design and manufacturing processes more efficient and reduce the time and cost to build aircraft. In FY 2020, NASA will complete the Advanced Composites Project, a six-year focused effort with industry to significantly reduce the time needed to develop and certify new composite structures for aerospace applications.

NASA is leading research into new components, technologies and powertrain architectures for electric or hybrid electric systems that can bring about revolutionary improvements in small and large transport aircraft. NASA's work on the X-57 Maxwell aircraft – an all-electric, general-aviation-size plane – already is delivering to the community important lessons about designing, building and operating an all-electric system. Industry will leverage NASA research to design and develop new vehicles. Building on these activities, NASA will refine concepts and technologies and validate new electric systems through ground and flight tests using the world-leading NASA Electric Aircraft Test Facility (NEAT) capable of conducting full scale ground test of high-power electric propulsion systems.

NASA has been conducting research to inform development of standards supporting safe integration of Unmanned Aerial Vehicles into the National Air Space, as well as new operating concepts such as UAS Traffic Management or UTM. UTM enables widespread low-altitude UAS operations by providing air traffic management services to UAS operators, as an intermediary between the FAA and UAS operators. NASA has collaborated with industry and the FAA to develop and test the UTM system through increasingly complicated flight trials at FAA test sites across the U.S. Industry-led domestic and international standards development organizations and trade groups have established working groups focused on UTM Services and supporting UAS technologies, and industry is investing in developing vehicles and systems and bringing them to market.

NASA is building on these experiences to enable creation of an urban air mobility or UAM system that is safe, economical and environmentally friendly. NASA is preparing a series of "Grand Challenges" that will provide a means to assess the maturity of key systems for Urban Air Mobility. Through these Grand Challenges, NASA will serve as a catalyst for companies to rapidly develop and demonstrate their capabilities in the U.S. while setting the course for the research, investment and regulations needed to realize the potential of UAM. NASA will identify critical barriers to UAM requiring NASA research such as assured autonomy and safe UAM vehicle operations and develop future research programs accordingly.

NASA continues a stable investment in unique specialized facilities and experts who conduct fundamental research to address key challenges in hypersonic flight, primarily in close coordination with the Department of Defense (DOD), to leverage DOD investment in ground and flight activities.

Space Technology

Question 25:

Restore-L, a proposed satellite-servicing mission, was estimated to cost about $700M dollars. This budget request restructures this effort, focusing instead on pursuing lower-cost ground-based demonstrations to help commercial markets and other government partners. How will NASA ensure that this effort does not duplicate other government efforts or compete with private sector investment?

Answer 25:

NASA sees substantial value in satellite servicing capabilities. However, there are already significant investments from industry and another Government Agency to develop commercial satellite servicing capabilities. Therefore, the Agency has proposed an alternative approach to enable a flight demonstration of satellite servicing technologies by leveraging commercial interests and developing capabilities in a cost-effective manner. In this proposal, NASA would continue development of the critical satellite servicing technologies to Technology Readiness Level (TRL) 6, while pursuing public-private partnerships with industry where commercial partners would propose which technologies in development they would demonstrate on their spacecraft based on their business plans. NASA believes the most cost effective approach is to utilize our technical expertise to develop these key technologies as ground developments, while leveraging the strong commercial interest to enable a flight demonstration through partnerships or Technology Transfer mechanisms. This will provide a clear path to transferring the technologies to industry for multiple applications without being in competition with private industry as well as minimizing duplication of efforts by other Government agencies.

Other

Question 26:

In 2013, this Committee heard testimony that 80 percent of NASA's infrastructure was beyond its constructed design life. Is this still the case? What can we do to ensure a key component of our nation's aerospace infrastructure does not fall into disrepair?

Answer 26:

NASA owns and manages a portfolio of facilities and real property with a total footprint of more than 500 square miles with a current replacement value of approximately $38 billion. Of that value, 80 percent is invested in constructed buildings and structures, predominantly technical in purpose and use. Likewise, as you note, 80 percent of NASA's facilities are more than 40 years old, and some have been in inventory for 80 years. Older facilities are more difficult and costlier to maintain, and are not designed to efficiently support the requirements of today's highly sensitive, technically evolved spacecraft and related hardware and systems. The advanced age of many of NASA's technical facilities also means that, despite ongoing maintenance, there is an intrinsic decline in quality and condition of the facilities, which creates risk to programs and projects that must be managed.

A challenge to managing NASA's highly technical programs is maintaining and modernizing facilities that were designed for an earlier age and purpose. NASA is addressing these challenges with infrastructure renewal policies that are founded on strategic facilities replacement goals for a gradual 25 percent Agency-wide reduction in facilities footprint over 20 years, as obsolete facilities are demolished and replaced with new, flexible-use, energy-efficient, sustainable structures. As these strategies are implemented, NASA continues to contend with the challenge of managing the demands of over $2.3 billion in deferred maintenance requirements. While NASA has made progress in holding steady the rate of increase through aggressive revitalization plans and demolition across its Centers, the ability to effect measurable reversal in the growth of these deferred requirements has remained elusive.

A well-functioning, efficient and cost-effective infrastructure is necessary for the support of NASA's mission requirements, and has a direct bearing on the level of risk to NASA mission objectives that must be managed. The availability of sufficient resources for NASA to meet these challenges of sustaining its infrastructure remains more critical than ever. NASA's FY 2020 budget request includes critical funding for construction and environmental projects to address these significant challenges. This funding will be important to enable NASA Centers to undertake actions that carry the Agency forward toward its infrastructure management objectives, including replacing obsolete capabilities with facilities that meet the demands of the missions of tomorrow.

Question 27:

NASA is the home to our nation's best and brightest minds. Does NASA see a need to change any of its employment policies? Are we prepared to maintain a vibrant and productive NASA workforce in the near- and long-term? Are there new, innovative, or even radical approaches to addressing this issue that should be more widely discussed?

Answer 27:

Yes, NASA sees a need to modernize employment policies and practices in order to maintain a vibrant and productive workforce in the near- and long-term. Already, NASA has had success in reducing hiring times from 90 days to 30 days. Additionally, working with OPM, NASA was recently approved for an extensive Direct Hire Authority for NASA, covering approximately 3,600 positions across 26 different occupations, authorized for the next 5 years. In addition, we are aggressively working to fill critical positions with our limited authority for excepted service positions designated in the Space Act (U.S. Code 51, Chapter 201, Section 20113(b)(1)). In order to attract, assign, and retain our Nation's best and brightest minds, NASA continues to evaluate programs already utilized in other Federal agencies with a large STEM workforce (i.e., National Nuclear Security Administration, DoD Research Labs, Intelligence Agencies, National Institute of Standards and Technology). Such programs include pay-banding, use of labor market sensitive pay setting, pay-for-performance, other financial and placement incentives, classification simplicity, and mobilizing "talent to task" via talent-based placement. NASA acknowledges that Congressional authorization would be needed to implement similar authorities for NASA.

Question 28:

The Administration has expressed interest in public-private partnerships. When used appropriately, funded Space Act Agreements are a useful tool to advance partnerships. NASA's current policy limits the use of funded Space Act Agreements to cases where contracts, grants, and cooperative research and development agreements cannot achieve agency objectives. This ensures that there is proper oversight of the use of funded Space Act Agreements. Does NASA intend to keep this policy in place?

Answer 28:

Yes, NASA intends to keep its policy in place in regard to the use of funded SAAs—that is, that such agreements are only used in cases where contracts, grants, and cooperative research and development agreements cannot achieve Agency objectives. Such instances have been very rare, as NASA has been able to effectively utilize Federal Acquisition Regulation (FAR)-based procurement mechanisms such as contracts to meet Agency objectives when a transfer of funding to a partner is involved. For example, in August 2018, NASA selected six U.S. companies to develop 10 "tipping point" technologies that have the potential to significantly benefit the commercial space economy and future NASA missions, including lunar lander and deep space rocket engine technologies. Another example would be the Commercial Lunar Payload Services (CLPS) contracts awarded to nine U.S. companies in November 2018, making them eligible to bid on NASA delivery services to the lunar surface as one of the first steps toward long-term scientific study and human exploration of the Moon and eventually Mars.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:

Administrator Bridenstine
Submitted by Congresswoman Bonamici

Question 1:

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

Answer 1:

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

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:
Administrator Bridenstine
Submitted by Congressman Crist

Question 1:

Can you comment on how you see CASIS, as the ISS National Laboratory organization, being utilized in the development and execution of the Commercial LEO Development program?

Answer 1:

The ISS National Lab, managed by CASIS, has been a key enabler of the expanded commercial use of LEO for research and technology development by private industry and other Government agencies. The ISS National Lab is currently opening up the possibilities of the Station research environment to a diverse range of researchers, entrepreneurs, and innovators that could create entirely new markets in space. These areas include, but are not limited to, drug delivery systems, crop science, regenerative medicine, reaction chemistry, materials science, fluid dynamics and transport phenomena, on-orbit production and microgravity-enabled materials, protein crystal growth (also known as macromolecular crystal growth), Earth observation, and remote sensing. The ISS National Lab portfolio's current positioning forecasts growth in the next ten years in areas such as cell and gene therapy, 3D bio-printing scaffolds, and aerospace projects using the LEO platform to raise technological readiness levels of next-generation LEO and beyond infrastructure systems. The ISS National Laboratory is helping to establish and demonstrate the market for research, technology demonstration, and other activities in LEO beyond the requirements of NASA.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

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

Question 1:

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

Answer 1:

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

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

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

- In 2017, NASA also utilized the NextSTEP-2 BAA for studies on approaches to the Power and Propulsion Element (PPE), including potential for leveraging commercially available capabilities and potential commercial interests. In September 2018, NASA released a solicitation for Spaceflight Demonstration for PPE, and in May 2019, selected Maxar Technologies. PPE is being developed as a public-private partnership leveraging industry capability and plans, demonstrating high-power solar-electric propulsion. In the solicitation, NASA specified only its unique requirements, allowing the industry partner to include their own objectives and requirements. The partner would own PPE through launch and an on-orbit demonstration lasting up to one year, after which NASA would have the option to acquire the PPE for use as the first element of Gateway.

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

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

Question 1a:

Has NASA conducted cost-benefit analyses on the use of multiple commercial vehicles to launch elements of the Gateway versus using SLS?

Answer 1a:

The Lunar Gateway will be launched on competitively procured commercial launch vehicles and assembled in orbit around the Moon where it will be used immediately as a staging point for missions to the lunar surface. It can evolve depending on mission needs, and will support human-class reusable landers, landing a crew of up to four astronauts on the lunar surface and ultimately developing sustaining lunar operations on the Moon. Delivery of Lunar Gateway and lunar lander elements, including refueling of these elements, will create a reusable hub for sustainable lunar activity and feed forward to Mars. In general, the cost to the government of a single SLS launch exceeds the cost of all commercial launch vehicles by hundreds of millions of dollars. However, the SLS offers capabilities that no existing commercial launch vehicle can replicate. Therefore, NASA plans to use SLS for missions for which its unique capabilities are required and use less expensive commercial launch vehicles for all other missions, consistent with the U.S. National Space Transportation Policy.

SLS will play an instrumental role in carrying out the Exploration Campaign objectives, as a critical component for delivering crew to the Lunar Gateway. The Agency will continue to identify and implement affordability strategies to ensure SLS can be a sustainable exploration capability for decades to come.

Question 2:

NASA's human spaceflight program has, for decades, involved low Earth orbit (LEO), including previous Shuttle missions and International Space Station exhibitions. How many LEO space suits does NASA currently have? How many of those suits can support extravehicular activities? What is the design-life of those suits and when will they need to be replaced?

Answer 2:

The current space suit used on the ISS is called the Extravehicular Mobility Unit (EMU). It is comprised of an anthropomorphic pressure garment (typically called the Space Suit Assembly or SSA) and the "backpack" which provides all the life support functions (typically called the Primary Life Support System or PLSS).

The modern day EMU fleet life began in 1978 during the Space Shuttle Program. These suits were originally certified with a life duration of 15 years. In the 1990s, NASA selected the EMU for use in assembling the ISS in lieu of developing a new design to meet the unique mission needs for the International Space Station (ISS) program. In 1993, the Agency commenced a life extension program referred to as the Assured EMU Availability (AEA) effort to methodically determine necessary steps for extending the life well beyond the original 15-year certification. Through this effort, components are certified for life extension, refurbished, or replaced, as necessary. Eighteen flight PLSS units were built since the inception of the EMU design, with the last unit delivered to NASA in 1999. Today, 11 flight units remain in inventory and are used supporting the ISS program, with typically four of these units on ISS at any one time.

As documented in the Advanced Space Suit Capability Plan delivered to Congress in June 2017, NASA is replacing some of the key components of the current EMU with the latest technology that will be used in the advanced space suit demonstration onboard the ISS. Components such as the carbon dioxide monitor and battery pack are being replaced. With the ongoing upgrades to the current EMU suit, at this time NASA does not believe there is a need for immediate initiation of a traditional acquisition to replace the heritage EMU on ISS.

Question 3:

Any return to deep space exploration will require space suits that can support crew, including crew visits to the lunar or Martian surface. Are lunar surface suits extensible to Mars or are different designs needed? What is NASA's plan for developing deep space suits and how will that plan change under a program that would send astronauts to the lunar surface in 5 years?

Answer 3:

In June 2017, pursuant the NASA Transition Authorization Act of 2017 (P.L. 115-10), NASA submitted to Congress its Advanced Space Suit Capability Plan. As the Agency works to determine the optimal approach to a human lunar landing by 2024, plans for the development of new suits for exploration will be revised. The space suits to be used for lunar surface exploration will have many components and technologies in common with those that will eventually support astronauts on the surface of Mars, and the Agency plans to take advantage of those commonalities. As there are differences between the lunar and Martian surface environments (e.g., characteristics of the dust), the Mars EVA suits will include elements tailored for that environment.

Question 4:

The FY 2019 budget proposed to end direct U.S. financial support for the International Space Station in 2025. Has anything changed in the FY 2020 budget request?

Answer 4:

NASA will continue its mission in low-Earth orbit (LEO) with the ISS to enable exploration with humans to the Moon and on to Mars, continuing to perform research that benefits humanity, supporting National Lab research by private industry and other organizations, and working towards reducing operations and maintenance costs. The Commercial LEO Development effort is providing resources for NASA to assist industry in developing a commercial LEO presence, with and without crews. Once these new commercial capabilities have been deployed in orbit, NASA will begin transitioning LEO operations to private industry. Together, NASA's ISS and Commercial LEO Development efforts will lay the foundation for the emergence of an environment in LEO where NASA is one of many customers of a non-Governmental human spaceflight enterprise.

Question 4a:

What is your plan for operating the ISS after 2024?

Answer 4a:

NASA's Commercial LEO Development effort is intended to stimulate both the development of commercially owned and operated LEO destinations from which

NASA can purchase services, and the continued growth of commercial activities in LEO where NASA is one of many users purchasing those services. As those commercial LEO destinations are available, and without a gap in human presence in LEO, NASA intends to implement an orderly transition from current ISS operations to the new commercial enterprise as laid out in NASA's ISS Transition Report of March 30, 2018. NASA will not have specific availability dates of commercial LEO destinations until the agency issues awards through the NextSTEP-2 BAA Appendices being used to support these destinations. The ISS Transition report may be accessed via the link below:

https://www.nasa.gov/sites/default/files/atoms/files/iss_transition_report_180330.pdf

Question 4b:

What does NASA plan to do in FY 20, 21, 22, 23, and FY 24 to transition from U.S. direct operations of the ISS?

Answer 4b:

Please see response to Question #4a, above. Further details can be found in the ISS Transition Report, which is updated biennially.

Question 4c:

What arrangements are you making with international partners regarding the end of U.S. direct financial support for operations?

Answer 4c:

One of NASA's ISS Transition Principles is to expand U.S. human spaceflight leadership in LEO and deep space exploration, including continuity of the relationship with our current ISS international partners. Consistent with the ISS Transition Principles, NASA will continue discussions with the ISS International Partners to help shape the long-term future of the ISS platform and LEO. Consultations with the ISS partners and stakeholders are essential to developing an implementation strategy that could result in the day-to-day execution of the ISS being performed by private industry. NASA is using the framework that currently supports cooperation on the ISS to facilitate partnerships on the lunar Gateway and on the surface of the Moon to ensure that current ISS partners have opportunities to collaborate with NASA on the full spectrum of future human exploration activities.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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

Questions for the Record to:

Administrator Bridenstine

Submitted by Congressman Perlmutter

Question 1:

How are current and future scientific research and development requirements being incorporated into the development and execution of both LEO commercialization and ISS transition plans?

Answer 1:

NASA will continue research and technology efforts in low-Earth orbit (LEO) using the International Space Station (ISS) to enable exploration with humans to the Moon and on to Mars, while continuing to perform research that benefits humanity and leads to a robust ecosystem in LEO, supporting ISS National Lab research by private industry and other organizations, and working towards reducing operations and maintenance costs. NASA is working to implement a step-wise transition of ISS from the current regime of NASA sponsorship and direct NASA funding, to a regime where NASA is one of many customers purchasing services from a LEO non-Governmental human space flight enterprise. NASA will gradually transition from current ISS operations to this new regime to ensure that the United States always has access to a crewed space station in LEO. As part of this transition, NASA plans to purchase needed LEO services from a commercial operator of ISS and/or new commercial LEO destinations. The full transition from ISS to new commercial LEO destinations will be gradual.

Over the next several years, the research program will continue to focus on capabilities needed to maintain a healthy and productive crew in deep space. Manifested or planned experiments and demonstrations to enable human exploration at the Gateway, lunar surface and into deep space include tests of improved long-duration life support, advanced fire safety equipment, on-board environmental monitors, techniques to improve logistics efficiency, in-space additive manufacturing, advanced exercise and medical equipment, radiation monitoring and shielding, human-robotic operations, and autonomous crew operations.

NASA has also developed and released to the public a forecast of future NASA demand for services in LEO. This forecast, which includes both research and technology development requirements, is intended to inform ISS transition and LEO commercialization efforts. It is available here: https://www.nasa.gov/leo-economy/long-term-needs.

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

January 16, 2020

Reply to Attn of: OLIA/2019-00121:RI:dac

The Honorable Kendra Horn
Chairwoman
Subcommittee on Space and Aeronautics
Committee on Science, Space,
and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairwoman Horn:

Enclosed are responses to written questions submitted by you and Rep. Bera resulting from the May 8, 2019, hearing entitled, "Keeping Our Sights on Mars: A Review of the NASA's Deep Space Exploration Programs and Lunar Proposal." The QFR material on the legacy of Apollo also addresses Rep. Bera's request made during the hearing.

This material completes the information requested during that hearing.

Sincerely,

Suzanne Gillen

Suzanne M. Gillen
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosure

November 2019

Apollo Impacts

NASA's Apollo Program captured the world's attention and demonstrated the power of America's vision and technology to inspire generations of great achievements, exploration, and scientific discovery. Our leadership in space continues.

Our goal 50 years ago was to land humans on the Moon and return them safely to Earth. Our goal now is to return to the Moon to stay, in a sustainable way.

The wide and deep impacts of Apollo include technology development and innovation, advances in science, as well as political, managerial and educational benefits. These benefits and NASA's ongoing work affect every aspect of our lives here on Earth.

Areas where the Apollo ripple effect is still being felt:

Complex Systems

Management of complex systems and structures was a critical legacy of Apollo. The push to the Moon helped us establish a truly national space program.

- Only the building of the Panama Canal rivaled the Apollo program's size as the largest non-military technological endeavor ever undertaken by the United States and only the Manhattan Project is comparable in a wartime setting.
- In order to execute Apollo, NASA needed to build the infrastructure – which included building four centers in the economically disadvantaged southern part of the country (Kennedy, Marshall, Stennis, and Johnson).

Technology

Apollo was a huge technological boost to the economy. Since Apollo was conducted as an open public program, largely executed by U.S. industry, the technology development was immediately incorporated into the public economy. Among many Apollo technological spinoffs:

- Helped spur the computer revolution – with the first Apollo contract being to develop the guidance computer;
- Miniaturization of technology to save space and weight;
- Cooling garments for medical, sports, and labor use;
- Improved dialysis machines based on technology for removing toxins;
- Water purification technology;
- Self-righting life rafts that have saved hundreds of sailors;
- Flame resistant textiles;
- Advanced technology for flying aircraft;
- Heat shield technology that now protects steel in buildings;
- Metallized insulation that protects homes, buildings and equipment;
- Lifesaving cardio pumps that had their origin in rocket development;
- Small rechargeable batteries now revolutionizing hearing aids;
- Rocket-powered parachutes to escape airborne mishaps;
- Personal locator beacons;
- Launch shock absorbers that now protect buildings from earthquakes;
- Improved freeze dried food and food safety practices.

Science

Apollo opened the door to the amazing science yet to be done on the Moon.

- Science from the Moon rewrote our understanding of the origin/history of the Moon and the solar system.
- Experiments placed on the Moon and samples returned from the surface have generated scientific findings ever since.
- Lunar rocks returned are nearly as old as our solar system.
- NASA also poured resources into American education during Apollo – building facilities and contributing to the development of faculty and labs at universities and colleges across the country.

People Pursuing Science, Technology, Education, and Mathematics (STEM) Careers

- The Apollo program demonstrated the strength of America's political and economic system and inspired an entire generation to pursue science and engineering careers.
- There was a threefold increase in these types of PhDs between the mid-1960s and the mid-1970s.

Public Engagement

- The inspirational nature of the program helped us see the planet in a new way.
- First Earth Day in 1970, post Apollo 8 "Earthrise" image and Moon landing.
- One-fifth of world's population at the time, 600 million, witnessed the Moon landing, a worldwide engagement that continues today on multiple social media platforms.

Apollo-Era Spinoffs

Tensile Fabrics Enhance Architecture Around the World
Spinoff 2009: https://spinoff.nasa.gov/Spinoff2009/ip_2.html

Using a remarkable fabric originally developed to protect Apollo astronauts, Birdair Inc., of Amherst, New York, has crafted highly durable, safe, environmentally friendly, and architecturally stunning tensile membrane roofs for over 900 landmark structures around the world. Travelers in airports, sports fans at stadiums, and shoppers in malls have all experienced the benefits of the Teflon-coated fiberglass fabric that has enabled Birdair to grow from a small company established in its founder's kitchen in 1955 to a multimillion-dollar specialty contractor today.

Food Safety Approach Becomes Industry Standard
Spinoff 1991: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//jsc/JSC-SO-165

As soon as NASA started planning to send people into space, it faced the problem of how and what to feed them. Johnson Space Center enlisted the aid of the Minneapolis-based Pillsbury Company to assure absolute freedom from potentially catastrophic disease-producing bacteria and toxins. Pillsbury came up with an approach that established control over the entire production process, from the raw materials to the processing environment and the people involved. Pillsbury developed the Hazard Analysis and Critical Control Point (HACCP) concept to prevent food safety problems rather than catch them after they occurred. The Federal Government now requires meat and juice producers to use HACCP programs, and all other food companies in the United States that have to register with the Food and Drug Administration, as well as foreign companies that export food to the United States, are switching to mandatory HACCP programs. Pillsbury plants still operate under HACCP

Fly-by-Wire Systems Enable Safer, More Efficient Flight
Spinoff 2011: https://spinoff.nasa.gov/Spinoff2011/t_5.html

Using the ultra-reliable Apollo Guidance Computer that enabled the Apollo Moon missions, Dryden Flight Research Center [now Armstrong Flight Research Center] engineers, in partnership with industry leaders such as Cambridge, Massachusetts-based Draper Laboratory, demonstrated that digital computers could be used to fly aircraft. Digital fly-by-wire systems have since been incorporated into large airliners, military jets, revolutionary new aircraft, and even cars and submarines.

Polymer Fabric Protects Firefighters, Military, and Civilians
Spinoff 2008: https://spinoff.nasa.gov/Spinoff2008/ps_3.html

In 1967, NASA contracted with Celanese Corporation, of New York, to develop a line of Polybenzimidazole (PBI) textiles for use in space suits and vehicles. In 2005, the PBI fiber and polymer business was sold to PBI Performance Products Inc., of Charlotte, North Carolina, under the ownership of the InterTech Group, of North Charleston, South Carolina. PBI Performance Products now offers two distinct lines: PBI, the original heat and flame resistant fiber; and Celazole, a family of high-temperature PBI polymers available in true polymer form. PBI is now used in numerous firefighting, military, motor sports, and other applications.

Shock Absorbers Save Structures and Lives During Earthquakes
Spinoff 2015: https://spinoff.nasa.gov/Spinoff2015/ps_2.html

With NASA funding, North Tonawanda, New York-based Taylor Devices Inc. developed fluidic shock absorbers to safely remove the fuel and electrical connectors from the Apollo spacecraft during launch. The company is now employing the technology as seismic dampers to protect structures from earthquakes. To date, 550 buildings and bridges have the dampers, and not a single one has suffered damage in the wake of an earthquake.

Freeze-Dried Food Nourishes Adventurers and the Imagination
Forthcoming, Spinoff 2020

In the early days of the space program, one problem was feeding astronauts during their time away from Earth. Food needed to be shelf-stable and long lasting, and it needed to pack small and light and be easy to prepare. Mercury astronauts complained about the bite-sized cubes, freeze-dried powders, and semi-liquids they were given. NASA funded research that improved and popularized freeze-drying, and the Ames Research Center visitor center got in touch with Boulder-based American Outdoor Products, looking for freeze-dried ice cream. The company, one of a few making freeze-dried products for consumers, developed a technique to meet the request, becoming the first to freeze-dry ice cream, which it still sells today as the popular astronaut ice cream sandwiches.

Fire-Resistant Reinforcement Makes Steel Structures Sturdier
Spinoff 2006: https://spinoff.nasa.gov/Spinoff2006/ps_3.html

Built and designed by Avco Corporation, the Apollo heat shield was coated with an ablative material whose purpose was to burn and dissipate energy. The burned material charred to form a protective coating, blocking heat. Avco subsequently contracted with Ames Research Center to develop spinoff fire-protection applications of the heat shield, such as fire-retardant paints and foams for aircraft. This led to the production of Chartek 59, made by Avco Specialty Materials (which was acquired by Textron Inc.) and marketed as the world's first intumescent epoxy. Chartek 59 expanded when exposed to heat or flames and acted as an insulating barrier. It also retained its space-age ablative properties and dissipated heat through burn-off. In 1999, Houston-based International Paint LLC acquired the Chartek brand. The company's latest product derived from the technology, Interchar, makes high-rise buildings and public structures safer. Interchar swells to provide a tough, stable insulating layer over the steel, protecting it without impacting the overall shape of the steel. Interchar provides up to four hours of fire protection and helps prevent steel structures from collapsing, giving occupants more time to evacuate.

Radiant Barrier Insulation Cuts Home Energy Bills
Spinoff 2013: https://spinoff.nasa.gov/Spinoff2013/cg_6.html

As NASA prepared to send people out on spacewalks, it needed a more powerful insulator than researchers could find. Reflective insulation existed, but in the 1960s, Marshall Space Flight Center created a "superinsulation" from layers of lightweight, metalized thin films that would become one of the Agency's most enduring spinoffs. They've been used in a host of building insulations, but RadiaSource, based in Woods Cross, Utah, uses a version that's metallized in such a way that the aluminum never oxidizes, letting the company offer a lifetime guarantee. In addition to rolls of insulation, the company offers kits for insulating garage doors and water heaters.

Reflective Coatings Protect People and Animals
Spinoff 2010: https://spinoff.nasa.gov/Spinoff2010/er_6.html

In the 1960s, Marshall Space Flight Center created a "superinsulation" from layers of lightweight, metalized thin films for use in spacesuits and spacecraft. Based on that invention, NASA engineers called upon National Metalizing Company to help create a reflective sunshield to deploy on Skylab in place of a shield that was lost during launch in 1973. Years later, a former employee for National Metalizing founded Advanced Flexible Materials (AFM) Inc., of Petaluma, California, and utilized the radiant barrier technology in the public domain to produce a variety of products such as wraps to keep marathon finishers safe from hypothermia as well as a lining for mittens and vests. Recently, the material helped to keep manatees warm as they were lifted from the water as part of a tag-and-release program.

Temperature-Resistant Materials Enable Space-Like Cold on Earth
Spinoff 2016: https://spinoff.nasa.gov/Spinoff2016/ip_3.html

In the 1960s, Marshall Space Flight Center created a "superinsulation" from layers of lightweight, metalized thin films for use in spacesuits and spacecraft. Since the 1980s, Dunmore Corporation of Bristol, Pennsylvania, has worked with the Jet Propulsion Laboratory and other NASA centers to develop variations on the technology, helping the company establish a massive catalog. Many of its multilayer insulations were developed for NASA and are now used in building insulation, cryogenic material transport, Magnetic Resonance Imaging (MRI) machines, and particle accelerators.

Space Blanket-Inspired Cases Protect Expensive Devices
Spinoff 2016: https://spinoff.nasa.gov/Spinoff2016/cg_4.html

Smartphones, laptops, and tablets are susceptible to damage if exposed to very high or low temperatures. Inspired by the "space blankets" he used as a Boy Scout, Nick Blanton, founder of Portland, Maine-based Salt Cases Company, developed fabric cases that incorporate multi-layer metallized thin-film insulation, known as radiant barrier, created by Marshall Space Flight Center decades ago.

Hutch Snuggle Keeps Outdoor Animals Comfortable
Spinoff 2005: https://spinoff.nasa.gov/Spinoff2005/ch_7.html

In the 1960s, Marshall Space Flight Center created a "superinsulation" from layers of lightweight, metalized thin films for use in spacesuits and spacecraft. Scratch and Newton Ltd., based in Leeds, England, employs this technology to improve the lives of pet rabbits and guinea pigs with its Hutch Snuggle protective coverings. The company also uses it to insulate pet water bottles with its Bottle Snug. Scratch and Newton has sold its products around the world.

Kegsheets Keep Beer Cold
Spinoff 2018: https://spinoff.nasa.gov/Spinoff2018/cg_6.html

NASA didn't invent reflective insulation, but the Space Agency mastered it in the form of layered metalized polyester thin films first made for Marshall Space Flight Center in the mid-1960s. Known as radiant barrier technology, this durable, lightweight "superinsulation" is used in all spacecraft and spacesuits and a host of applications on Earth. JUNTO LLC, based in Boston, now uses the technology to make KegSheets, which, coupled with ice, can a keep beer keg cold all through a hot day.

Rechargeable Hearing Aid Batteries Draw from NASA Research
Spinoff 2017: https://spinoff.nasa.gov/Spinoff2017/cg_4.html

Several early NASA spacecraft, including the Apollo command module, used silver-zinc batteries. NASA spent much effort trying to develop a rechargeable silver-zinc battery, as the pairing offers a higher power-to-weight ratio than any other battery couple. Significant advances in the batteries' durability were made at Glenn Research Center, which ZPower of Camarillo, California, used as part of its starting point, undertaking years of additional development before releasing its rechargeable hearing aid batteries, the first that can last all day on a single charge.

Cooling Garments Find Medical, Athletic, and Industrial Uses
Spinoff 2017: https://spinoff.nasa.gov/Spinoff2017/hm_4.html

In the 1960s and '70s, Bill Elkins worked with engineers at NASA and the U.S. Air Force, including several at Ames Research Center, on liquid cooling garments to be worn under spacesuits and flight suits. He has spun that experience off into several companies, including Downers Grove, Illinois-based WElkins LLC. The company markets varieties of the cooling technology to prevent brain damage after heart attacks or strokes, improve sports performance, treat concussions, and keep workers from overheating under heavy protective gear.

Spacesuit Production Leads to Lighter-Than-Air Vehicles
Spinoff 2005: https://spinoff.nasa.gov/Spinoff2005/ch_1.html

Through its work with spacesuit designing, testing, and manufacturing for Johnson Space Center, beginning with the Apollo missions, ILC Dover developed skills and processes unique to the industry. The Frederica, Delaware-based company uses the same high-performance, rugged textiles, high-strength seaming technology, and test methods developed for spacesuits to make a majority of the large lighter-than-air vehicles in use around the world.

Apollo-Era Life Rafts Saved Hundreds of Sailors
Spinoff 2009: https://spinoff.nasa.gov/Spinoff2009/ps_3.html

To keep life rafts holding astronauts from capsizing in the downdraft of rescue helicopters after Apollo splashdown landings, engineers at NASA's Johnson Space Center designed and patented a self-righting life raft capable of staying upright in choppy seas and fierce winds. Givens Marine Survival Co. Inc. of Tiverton, Rhode Island, licensed this invention and manufactured the rafts under the name Givens Buoy Life Raft in a variety of sizes and models. The company no longer exists, but Givens sold several thousand of the ballasted, inflatable life rafts, which were credited with saving the lives of hundreds of sailors.

Containment System Improves Pharmaceutical Manufacturing
Spinoff 2005: https://spinoff.nasa.gov/Spinoff2005/ch_1.html

Through its work with spacesuit designing, testing, and manufacturing for Johnson Space Center, beginning with the Apollo missions, ILC Dover developed skills and processes unique to the industry. The DoverPac, a series of high-strength, flexible, transparent tubes, provides reliable containment of highly active ingredients in powder form. The heat sealing technology, the woven bladder design, and the design of the woven-mesh outer restraint are all based on work the Frederica, Delaware-based company did for NASA.

Escape Respirators Keep Civilians Safe
Spinoff 2005: https://spinoff.nasa.gov/Spinoff2005/ch_1.html

Through its work with spacesuit designing, testing, and manufacturing for Johnson Space Center, beginning with the Apollo missions, ILC Dover developed skills and processes unique to the industry, applying them to various products. The Frederica, Delaware-based company's civilian escape respirators use the same heat seals and the same quality and inspection that keep NASA's astronauts safe in space. While traditional gas masks demand multiple sizes to fit the population, require extensive training, and are not designed for children or infants, ILC's masks are easy to use and come in one size that fits anyone.

Anti-Reflective Coatings Improve Display Screens
Spinoff 1989: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//hdqs/HDQS-SO-133

In 1963, Optical Coating Laboratory Inc. (OCLI) developed HEA (for high-intensity antireflection) coating to improve visible light in the Gemini spacecraft. In the days of cathode ray tube-based televisions and computers, screen glare was a common complaint, and OCLI made a name for itself selling HEA-coated panels to manufacturers, as well as a line of retrofit products, all of which reduced screen glare. In 2014, MAC Thin Films took over the Santa Rosa, California-based operation. Today, HEA coatings improve the clarity and color fidelity of touch screens, handheld instruments, Global Positioning System (GPS) displays, medical displays, digital signage, and more.

Metal Coatings Find Thousands of Applications
Spinoff 1994: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//hdqs/HDQS-SO-85

During the Apollo Program, General Magnaplate Corporation developed process techniques for bonding dry lubricant coatings to space metals. The coatings were not susceptible to outgassing and offered enhanced surface hardness and superior resistance to corrosion and wear. This development was necessary because conventional lubrication processes were inadequate for lightweight materials used in Apollo components. General Magnaplate built on the original technology and became a leader in the development of high-performance metallurgical surface enhancement coatings. The company now has nearly two dozen coatings that have been used in virtually every NASA spacecraft and spacesuit since Apollo, as well as applications from pizza making to laser manufacturing, injection molding, heat sinks on computers, and the boring machines that dug the "chunnel" between France and England. Each of the coatings is designed to protect a specific metal or group of metals to solve problems encountered under operating conditions.

Water Treatment Systems Make a Big Splash
Spinoff 2004: https://spinoff.nasa.gov/Spinoff2004/er_1.html

In the 1960s, NASA's Manned Space Center (now known as Johnson Space Center) and the Garrett Corporation, Air Research Division, conducted a research program to develop a small, lightweight water purifier for the Apollo spacecraft that would require minimal power and would not need to be monitored around the clock by astronauts. Carefree Clearwater Ltd., of Atlanta, Georgia, obtained NASA's permission to manufacture a modified version of the space agency's patented purification technology for numerous commercial and industrial applications, including swimming pools, hot water spas, decorative fountains, ponds, manufacturing processes, and evaporative water cooling towers. The company's systems electronically release copper and silver ions into the water to destroy bacteria and algae, which are then filtered out. Unlike chlorine, the ions do not dissipate from heat and sunlight. The technology reduces the need for chlorine, cutting down on burning eyes, odor, and bleached or dry skin and hair. And the ions pose no health risks.

Space Pens Work Under Any Conditions
Spinoff 1986: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//hdqs/HDQS-SO-144

Most pens rely on gravity to draw out ink. Fisher's Space Pen was developed for the Apollo astronauts to use in a gravity-free environment. The cartridge is pressurized with nitrogen to force ink outward toward the ball point. The "thixotropic," rubber-like ink is almost solid and only liquefies with friction from the ballpoint. The pen operates at temperatures from - 30 to 250 °F, can withstand atmospheric extremes, and even writes underwater. Fisher Pen Company's 65 employees now make dozens of variations on the original AG-7 Antigravity Pen at their warehouse in Boulder City, Colorado. The pens have been used on every crewed NASA mission since their invention.

Archiving Innovations Preserve Essential Historical Records
Spinoff 2012: https://spinoff.nasa.gov/Spinoff2012/it_6.html

The Apollo 11 mission left on the Moon a silicon disc inscribed with microscopic recreations of messages from 73 countries. NanoArk Corporation of Fairport, New York, built on that NASA technology to develop a fire- and water-resistant archiving innovation that provides cost savings and security in preserving documents.

Space-Proven Medical Monitor Is Part of Total Patient Care Package
Spinoff 2006: https://spinoff.nasa.gov/Spinoff2006/hm_2.html

Spacelabs Medical, now Spacelabs Healthcare, was cofounded by Ben Ettelson and James A. Reeves in 1958 to work with NASA and the U.S. Air Force on systems to monitor the vital signs of astronauts in space. As a prime contractor to NASA for the Gemini Program, the company manufactured and delivered prototypes of miniaturized signal conditioners to measure astronauts' temperature, respiration, and cardiac activity. The company then brought that technology down to Earth to dramatically change the course of patient monitoring. Today, the company's Intesys Clinical Suite enables easy access to patient information. One component of this suite is the Vital Signs Viewer, which allows physicians to see a patient's live waveforms and other data remotely from any networked personal computer outside of a hospital. With the suite's AriaTele telemetry transmitter and Xhibit central station, patients can be monitored constantly and comprehensively.

Liquid Cooling Technology Increases Exercise Efficiency
Spinoff 2015: https://spinoff.nasa.gov/Spinoff2015/hm_3.html

To keep astronauts' airtight spacesuits from becoming hot and humid, Ames Research Center developed liquid cooling garments that were integrated into each suit's long underwear. Vasper Systems, in San Jose, California, is using the technology in its liquid-cooled compression cuffs, which help people exercise more efficiently by concentrating lactic acid in their muscles.

Gas Regulators Keep Pilots Breathing
Spinoff 2019: https://spinoff.nasa.gov/Spinoff2019/ps_2.html

Since John Glenn's first orbit in 1962, all U.S. astronauts have used a derivation of his oxygen regulator. For the original project, Cobham Mission Systems (then operating as Carleton Controls) needed to make a gas regulator smaller and lighter than ever before. Now the Orchard Park, New York-based business uses the innovative spring design it created for Johnson Space Center and its oxygen safety expertise in oxygen systems for pilots, as well as for applications like wastewater treatment and offshore drilling.

Cordless Power Tools Offer Freedom of Movement
Spinoff 1981: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//jsc/JSC-SO-105

Apollo astronauts needed a portable, self-contained drill capable of extracting core samples as much as 10 feet below the lunar surface. Black & Decker used a specially developed computer program to optimize the design of the drill's motor and insure minimal power consumption. Refinement of the original technology led to the development of a cordless miniature vacuum called the Dustbuster. It has no hose and no cord, and comes with a storage bracket that serves as a recharger. Other home-use cordless instruments based on the technology have included drills, shrub trimmers, and grass shears. The company also manufactures a number of cordless tools used in the sheet metal, automobile, and construction industries, as well as a line of cordless orthopedic instruments.

Spacesuit Techniques Improve Athletic Shoes
Spinoff 1991: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//hdqs/HDQS-SO-193

Al Gross transferred expertise obtained as an ILC Dover engineer for NASA's Apollo program to the manufacture of athletic shoes for Beaverton, Oregon-based Avia Inc. Gross substituted DuPont's Hytrel plastic for foam materials in the shoe's midsole, eliminating cushioning loss caused by body weight. An external pressurized shell from spacesuit technology was incorporated into the shoe. Stiffness and cushioning properties of the midsole were tuned by varying material thickness and styling lines. A stress-free "blow molding" process adapted from NASA spacesuit design was also utilized. The resulting compression chamber midsole performed well in tests. It allowed Avia to reconfigure for specific sports and was a "first step" toward a durable, foamless, non-fatiguing midsole.

Fire-Resistant Fabric Increases Safety
Spinoff 1982: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//jsc/JSC-SO-29

Fire hazard is greater in atmospheres containing a high concentration of oxygen under pressure, such as the Apollo capsule. NASA intensified its fire safety research after the 1967 Apollo fire. Under contract to Johnson Space Center, Monsanto Company developed a chemically treated fabric called Durette. The material was used for a wide range of applications such as sheets, attendants' uniforms in hyperbaric chambers, and crew's clothing, furniture, and interior walls in diving chambers, as well as suits for auto racers, refuelers, and crew chiefs. Durette bags filtered gases and dust from boilers and electric generators. Today, Amron International Inc. of Vista, California, a company that specializes in diving, tactical, hyperbaric, and outdoor equipment, sells Durette coveralls, pillows, mattresses, and sheets.

NASA Parachute Innovations Carry Commercial Rockets Back to Earth
Spinoff 2017: https://spinoff.nasa.gov/Spinoff2017/t_3.html

Airborne Systems Inc., whose Space and Recovery Systems branch is in Santa Ana, California, worked as a subcontractor to build the parachute system for the Orion capsule. The design is based in part on the Apollo spacecraft's parachutes but incorporates updates and improvements requested by Johnson Space Center, which managed the contract. Johnson also carried out drop tests to prove the parachutes, which Airborne Systems now sells to several commercial spacecraft companies.

Apollo 11 History Archive Helps Virtual Reality Program Come to Life
Spinoff 2018: https://spinoff.nasa.gov/Spinoff2018/cg_1.html

So much NASA data is available online that Waterford, Ireland-based Immersive VR Education was able to recreate the first Moon landing as a highly realistic and rich virtual reality experience. NASA Headquarters maintains a vast trove of images, design plans, data, and more, with the Lunar Surface Journal among its most popular records. The company's Apollo 11 VR, an app which lets users experience Apollo 11 from takeoff to the lunar surface and back to Earth reentry, has sold more than 40,000 copies.

Workout System Improves Muscle, Cardiovascular Strength
Spinoff 1993: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//hdqs/HDQS-SO-183

In the mid-sixties, Gary Graham, a Boeing designer, developed a cardiovascular conditioner for a planned U.S. Air Force orbiting laboratory. After the project was cancelled, Graham participated in space station conditioning studies for NASA's Apollo Applications (later Skylab) Program. Twenty years later, he used this expertise to develop the Shuttle 2000-1, a physical therapy and athletic development conditioner that's still available today through Bellingham, Washington-based Shuttle Systems, along with several variations. Football teams, sports clinics, and medical rehabilitation centers have all used the machines over the years. They use both kinetic and plyometric exercises to promote cardiovascular fitness and muscular strength development.

Plasma Heating Promises Environmentally Friendly Waste Disposal
Spinoff 1994: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//arc/ARC-SO-55

The Mercury and Apollo spacecraft shields were designed to protect astronauts from temperatures well over 2,000 degrees Fahrenheit when re-entering the Earth's atmosphere. It was necessary to test and verify the heat shield materials before spaceflight. NASA decided to use plasma heating as a heat source, a technique that involves passing a strong electric current through a rarefied gas to create a plasma that produces an intensely hot flame. Although NASA did not invent the concept, its work expanded the market for commercial plasma heating systems. A member of the team that developed the Reentry Heating Simulator at Ames Research Center, Salvador Camacho, founded Plasma Technology Corporation, believing the technology had applications in environmentally friendly waste disposal. The company no longer exists, but the technology does. In 2014, Columbia Ridge Landfill in Arlington, Oregon, became the first U.S. site to demonstrate plasma gasification technology to convert waste to fuel.

Sorbent Dialysis Allowed Patients Greater Freedom
Spinoff 1992: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//jsc/JSC-SO-89

Organon Teknika Corporation's REDY 2000 dialysis machine employed technology originally developed under NASA contract by Marquardt Corporation. The chemical process developed during the project could be applied to removing toxic waste from used dialysis fluid. This discovery led to the development of a kidney dialysis machine using "sorbent" dialysis, a method of removing urea from human blood by treating a dialysate solution. The process saved electricity, and because the need for a continuous water supply was eliminated, patients had greater freedom. The technology fell out of use, but researchers have talked about reviving it in the form of a "wearable kidney."

Cooling Suit Treated Medical Conditions
Spinoff 2005: https://spinoff.nasa.gov/Spinoff2005/ch_1.html

Based on its work with the liquid-cooling systems used to regulate astronaut body temperature in the spacesuit, ILC Dover created the Cool Vest, a lightweight cooling garment designed to reduce the effects of heat stress. It was used to lower the body temperatures of people suffering from hypohidrotic ectodermal dysplasia, a rare disease in which the sufferer is lacking in sweat glands, as well as to lessen the effects of heat-related symptoms in people suffering from multiple sclerosis. The vest also had applications in rigorous industrial environments where elevated temperatures can be debilitating. The Frederica, Delaware-based company no longer makes the product.

Insulation Kept Alaska Pipeline Oil Warm
Spinoff 1979: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//hdqs/HDQS-SO-91

Crude oil moving through 800 miles trans-Alaska pipeline must be kept at relatively high temperature—approximately 180 °F—to maintain the oil's fluidity. In the 1970s, the Space Division of the General Electric Company (GE) provided a product called Therm-O-Trol, a metal-bonded polyurethane foam especially formulated for Arctic insulation. Another problem was solved using Therm-O-Case, a double-walled oil well casing with multi-layered insulation to provide a protective barrier against heat transfer. Without it, heat transfer could have melted the frozen terrain and caused dislocation that could have destroyed expensive well casings. Both products evolved from work GE did on thermal management for Gemini, Apollo, and other NASA programs.

Hydrogen Generator Provided Cooling for Power Plant
Spinoff 1983: https://spinoff.nasa.gov/database/spinoffDetail.php?this=/spinoff//jsc/JSC-SO-84

Under contract to Johnson Space Center, General Electric Company developed a hydrogen generator for use in the fuel cell power system of the Gemini spacecraft. By 1982, the Sewaren generating station of Public Service Electric and Gas Company in New Jersey was using the technology to cool its large generators.

Controlled Blasts Allowed Quick Forced Entry, Demolition
Spinoff 1976: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19760009897.pdf

Explosive Technologies Inc. developed a linear blasting technique to separate stages of the Gemini launch vehicle. In the late 1960s, the company commercialized the technology as Jetaxe, which allowed firefighters to quickly cut entrances and ventilation holes, and the higher-powered Jetcord for controlled demolitions. The products were sold for about 10 years.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

Keeping Our Sights on Mars: A Review of NASA's Deep Space Exploration Programs and Lunar Proposal

Questions for the Record to:

Mr. Gerstenmaier and Mr. Sirangelo (NASA)

Submitted by Chairwoman Horn

Question 1-1a:

Mr. Gerstenmaier noted on April 30 at the joint Space Studies Board/Aeronautics and Space Engineering Board meeting at the National Academies that the proposed 2024 Moon landing would be "minimalist." How long will the first mission on the lunar surface last? What activities will the astronauts conduct?

Could these activities be performed by robotic missions?

Answer 1-1a:

NASA anticipates that Artemis 3 (the crewed landing, in 2024) would be a shorter lunar surface sortie than future missions, which are planned to last about seven days. The concept of operations for surface activities for the Artemis 3 crew is under review.

Question 1b:

Is an earlier mission going to pre-place cargo on the surface in preparation for the human landing, and if so, are precision landing capabilities sufficient to land astronauts nearby?

Answer 1b:

Logistics for Artemis 3 will rendezvous and dock at the Gateway and prior to the astronauts descending to the surface, the logistics will be transferred into the Human Landing System. For the surface landings, NASA is advancing precision landing capabilities that can be applied to lunar missions. This includes:

- Navigation Doppler Lidar, which provides direct velocity and ranging measurements using Doppler-based techniques;

- Hazard Detection Lidar, capable of generating a real-time, 3-D terrain map within a 50-meter radius of the landing target, at a sufficient range to allow for safe landing site determination;
- Algorithms for performing guidance and navigation, including Terrain Relative Navigation (TRN) and Hazard Detection; and
- Advanced computing capabilities, via a high performance space computing-based platform with a path to spaceflight, capable of supporting processing-intensive algorithms for navigation and image processing.

NASA is also considering whether the Science Mission Directorate's Commercial Lunar Payload Services (CLPS) contract vehicle could be used to deploy small robotic landers to either scout potential landing sites or pre-position other equipment on the lunar surface.

Question 1c:

When would the second mission occur, and how often would NASA anticipate subsequent missions occurring?

Answer 1c:

Notionally, Artemis 4 would be launched in late 2025, and further missions would take place at approximately yearly intervals.

Question 2:

Can you explain in clear terms what new risks, if any, NASA is proposing that the U.S. Government and the American people accept in carrying out the 2024 accelerated Moon landing? What, specifically, would NASA do to drive down that additional risk to the lowest possible level?

Answer 2:

The acceleration of the crewed Moon landing does not represent a fundamentally new program, but a faster path to achieve NASA's existing objectives. While recognizing the technical risk involved with this acceleration, the Agency has the capability to retire or manage that risk, given the appropriate resources.

Question 3:

Will the NextSTEP-2 Broad Agency Announcements (BAAs) for the Gateway element architecture provide "significant commercial applications beyond NASA" as stated in NASA's NextSTEP-2 document?

Answer 3:

NASA intends for the Gateway to involve commercial partners and to support their activities on and near the Moon. The first element of the Gateway – the Power and Propulsion Element (PPE) – will be provided by Maxar Technologies as a public-private partnership. The solar-electric propulsion (SEP) system used by the PPE has extensive applications for commercial satellites, enabling station keeping and on orbit transfer.

Question 3a:

What evidence will NASA require of the proposers regarding any commercial lunar market?

Answer 3a:

NASA defers to proposers regarding their wider commercial business case, but the Agency intends to utilize commercial services in support of its lunar exploration program, including commercial launch and logistics delivery services as well as Commercial Lunar Payload Services (CLPS) for the delivery of science and technology payloads to the lunar surface, and ultimately the procurement of crew transportation to the lunar surface as a commercial service. In doing so, the Agency hopes to expand the commercial market into cislunar space and onto the lunar surface.

Question 3b:

Will the government own the intellectual property associated with the systems developed under NextSTEP?

Answer 3b:

To facilitate the commercial development of critical technologies needed for human space exploration, NASA takes steps to ensure that its contractors and partners retain the maximum rights permitted by law, unless NASA has identified a specific need to obtain rights in intellectual property for NASA's own purposes. It is part of NASA's mission to "seek and encourage the fullest commercial use of space," so it is NASA's intent to ensure that its contractors and partners are able to leverage investment to advance commercial space activities.

Question 4:

What is the safety policy associated with Gateway, surface landing, and other capabilities that would be developed under the BAA, and does it apply to government astronauts?

Answer 4:

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. Deep space exploration missions hundreds of thousands of miles from Earth bring an additional set of risks beyond those associated with regular crew missions to LEO. These risks include higher spacecraft re-entry velocities, much greater radiation exposure

associated with travel through and beyond Earth's magnetic system, etc. In recognition of these and other risks associated with deep space missions, NASA has developed draft Crewed Deep Space Systems Certification Requirements and Standards for NASA Deep Space Missions (HEOMD-003). These requirements are built upon NASA's unique human spaceflight knowledge and experience. The intent of this document is to define the requirements, standards, and certification package contents that will be used to certify systems to carry NASA or NASA-sponsored crewmembers on deep space missions. The draft document has been provided to the NextSTEP-2 Appendix E awardees for their review, understanding, and comment as they mature their human lunar landing concepts. NASA plans to work closely with these vendors and other deep space exploration contractors beginning early in the design lifecycle to address their concerns and ensure their plan for meeting the deep space requirements and standards presents an acceptable level of risk to the
Agency and our astronauts.

Question 4a:

If there is an accident, will NASA have immediate access to information on hardware pedigree, certification of parts, qualification of materials, and prior testing and analyses?

Answer 4a:

Yes.

Question 5:

How is NASA prioritizing sustainability in developing the plans for a 2024 human lunar landing?

Answer 5:

For Artemis 3, the prime focus is on a crewed landing on the lunar South Pole in 2024, with future Artemis missions building up and utilizing a sustainable infrastructure around and on the Moon. Even this initial mission, however, will support the longer-term goal of sustainability in three key respects: 1) Artemis 3 will use systems developed for NASA's deep space architecture (e.g., the Space Launch System, Orion, Exploration Ground Systems, the initial Lunar Gateway, and a human landing capability); 2) the focus on near-term results is intended to promote constancy of purpose in the long run through demonstrating the feasibility and the benefits of human exploration; and 3) NASA expects that the public-private partnerships that will be used to develop human lunar lander systems will bring innovative solutions to the table that could significantly reduce the cost and increase the sustainability of subsequent surface missions.

Question 5a:

Will NASA require it in any contracts?

Answer 5a:

NASA aims to create a sustainable deep space infrastructure that will enable access to any part of the Moon as needed. To the extent that the Agency can reasonably incorporate elements supporting that goal in near-term contract mechanisms, it will do so, but the focus of Artemis 3 is effecting a crewed landing on the lunar South Pole in 2024.

Question 5b:

Which elements of the 2024 landing (e.g., the initial space suits, a small habitation module, the integrated human lander) would be sustainable or reusable?

Answer 5b:

The two elements of the Gateway that will be deployed to support the 2024 landing (the Power and Propulsion Element and Habitation and Logistics Outpost (HALO) will be fully used by subsequent missions. The specifics of the Artemis 3 surface elements, such as space suits and human landing system, will be determined as we move forward.

Question 6:

Will preparation for a lunar field station be included in NASA's amended five-year budget proposal?

Answer 6:

No, NASA's plans for lunar surface assets, such as a field station, are in development, and not specifically supported in the amended FY 2020 budget request.

Question 6a:

If yes, what exactly this lunar field station will be and what it will do? Is it envisioned to be robotic, occasionally crewed, or permanently crewed?

Answer 6a:

There are a variety of potential configurations, user communities, and purposes (e.g., scientific research, technology or resource development) for future lunar surface assets.

Question 6b:

What is the timeline for a lunar field station?

Answer 6b:

The development timeline for a lunar field station will be reflected in future budget requests.

Question 6c:

What, if any, entities other than NASA would you anticipate using the lunar field station, and would they be contributing funding to develop it?

Answer 6c:

The specifics of a lunar field station have not been determined at this time.

Question 7:

The Congressionally-directed Mars 2033 report stated that "internal NASA planning documents do not adequately justify why many of the scientific activities that may be conducted on the Gateway could not be performed using solely robotic means." To what extent has the science community determined the relative priority of carrying out science on the Gateway versus science on the International Space Station, or a free-flying spacecraft?

Answer 7:

The Gateway will fly in a different environment than does ISS (with different levels of radiation, and thermal cycling), and at different distances from potential investigation targets (e.g., Moon and Earth). Gateway will be crewed for periods of time, offering the potential for astronaut interactions with investigations (e.g., changing out samples, adjusting instruments). These physical differences between ISS and Gateway could potentially support different lines of scientific inquiry than are possible on ISS while also presenting different financial, operational, and technical constraints.

In February 2018, NASA held a Gateway Science Workshop with these primary objectives:

1. Engage the science community with respect to the scientific potential of a lunar gateway
2. Discuss potential scientific investigations leveraging the gateway
   - including the scope of possible instruments
   - using the gateway infrastructure
3. Discuss what resources the gateway would have to provide to facilitate different types of scientific investigations

There were approximately 300 attendees from government, industry, and academia with ~180 talks covering discipline-focused areas (e.g., heliophysics, Earth science, astrophysics and fundamental physics, lunar and planetary, and life sciences and space biology) as well as cross-cutting discussions on topics including, but not limited to, external instruments, telerobotics, and orbits.

Key takeaways from the science community from this workshop were:

- Gateway, in Near-Rectilinear Halo Orbit (NRHO), offers unique opportunities across all science disciplines;

- Externally mounted sample collection with controlled pointing can collect samples and provide important science about cometary material, solar composition, interstellar particles, and near Earth objects; and
- Radiation environment of the Gateway can provide important tests of the effects of radiation on biological organisms.

Input on infrastructure capabilities to perform robust science was also derived including:

- With additional transportation infrastructure (Low Lunar Orbit transfer vehicle, surface access, sample return capability) Gateway can enable additional important lunar science; and
- Science utilization extremely constrained until the presence of an external robotic arm.

Question 8:

How will NASA respond to the Aerospace Safety Advisory Panel (ASAP) recommendation that NASA "immediately" transition to new space suits for space walks outside of the International Space Station?

Answer 8:

A: NASA is developing a flexible spacesuit architecture with common core subsystems that can be modified to support the needs of specific destinations from low-Earth orbit to the lunar surface. NASA intends to demonstrate the core spacesuit technologies and subsystems applicable to both ISS-based operations and surface exploration through a series of subsystem demonstrations at ISS beginning in 2019 and culminating in delivery of a complete suit system in 2022 or 2023 for an on-orbit demonstration at ISS prior to the 2024 lunar mission.

Question 9:

Has NASA made a final decision on whether or not it will proceed with the full Green Run ahead of EM-1? If so, have any changes been made to the original testing content, and why?

Answer 9:

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

During the Green Run testing, engineers will install the core stage that will send Orion to the Moon in the B-2 Test Stand at NASA's Stennis Space Center near Bay St. Louis, Mississippi for a series of tests over several months. The term "green" refers to the new hardware that will work together to power the stage, and "run" refers to operating all the components together simultaneously for the first time. Many aspects will be carried out for the first time, such as fueling and pressurizing the stage, and the test series culminates with firing up all four RS-25 engines to demonstrate that the engines, tanks, fuel lines, valves, pressurization system, and software can all perform together just as they will on launch day.

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

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

Question 9a:

If not, when will you make the decision?

Answer 9a:

Please see response to Question #9, above.

Question 10-10a:

The Congressionally-directed Mars 2033 report indicated that, under the previous 2028 lunar landing plan, NASA would need to begin systems development of a Mars deep space transport spacecraft in 2024 in order for it to be ready for a 2039 human mission to orbit Mars.

- o What timeframe does the current lunar plan assume for a future crewed mission to the surface of Mars?

Answer 10-10a:

NASA is focused on creating a sustainable presence on the Moon as a stepping-stone for future human missions to deep space destinations, including the surface of Mars. The Agency intends that the technologies and operational techniques developed in the relatively nearby proving ground of cislunar space feed forward to Mars missions. As our near-term activities on the Moon inform our planning for Mars missions, those details will be reflected in future editions of the biennial National Space Exploration Campaign report to Congress, the first edition of which was submitted in September 2018.

Question 10b:

When would NASA plan to initiate development of a Mars deep space transport?

Answer 10b:

Please see response to Question #10a, above.

Question 11:

How would Entry, Descent, and Landing (EDL) technology developed for the lunar surface be useful toward a landing of humans on Mars?

Answer 11:

Given that Mars has an atmosphere, there are substantial technical differences between the entry, descent, and landing, and ascent environments of Mars and the Moon. However, precision landing technologies used to safely land on the lunar surface, will also improve landing accuracy on Mars. These technologies were described in greater depth in the response to Question #1b, but include Navigation Doppler Lidar, Hazard Detection Lidar and Terrain Relative Navigation, which will have its first infusion on the Mars 2020 mission. Techniques for integrated guidance, navigation, and control during powered landing can be leveraged from the Moon, for Mars. NASA is also starting to gather data to better model the interactions between lunar landers and the lunar surface. Although some of the physics are different, the modeling methods developed for lunar vehicles can be modified to apply to Mars landings. NASA also envisions that technologies associated with a lunar ascent vehicle could be applicable to a future Mars ascent vehicle. While a nominal Artemis mission would involve the lunar ascent vehicle rendezvousing with the transfer vehicle for a return to the Gateway, the ascent vehicle will have an abort capability that would enable it to fly directly to the Gateway without this rendezvous.

NASA is also developing the Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) as an atmospheric entry system with its first applications for returning rocket stages and cargo to Earth. NASA expects to demonstrate this system in partnership with United Launch Alliance in 2022, proving the technology for both Earth return of payloads as well as for future Mars entry of large mass.

Question 11a:

What further development work will need to be done between the lunar landing effort and a Mars landing effort?

Answer 11a:

Among the most important capabilities NASA would develop for a Mars landing mission would be those associated with transit (both the physical vehicle and the propulsion system); Mars atmospheric entry and descent vehicle (which could rely on technologies such as a hypersonic inflatable decelerator and/or supersonic retropropulsion as well as integrated guidance, navigation and control); Mars ascent vehicle (which could be an evolution of the lunar ascent module); surface suits (which would be informed by the Agency's lunar surface suit experiment, though the hardware would have to be optimized for the Martian surface environment); and surface power systems (which could be an evolution of future lunar surface power systems). The experience with lunar *in situ* resource utilization would inform plans to conduct ISRU activities on the surface of Mars, as well.

Question 11b:

When does NASA plan to initiate Mars-specific EDL work for a human landing on Mars?

Answer 11b:

Please see response above to Question #10a.

Question 12:

The recent National Academies consensus study report, *A Midterm Assessment of Implementation of the Decadal Survey on Life and Physical Sciences Research at NASA* recommended that NASA adopt a "cautious approach" when shifting and focusing the NASA research portfolio toward more exploration-focused research, because basic research can have major impacts, sometimes unexpected ones, in the long term. How is NASA responding to this recommendation?

Answer 12:

NASA agrees with the Academies' view of the value of basic research; we are striving to achieve balance between basic research, exploration-focused research, and technology development. The Space Life and Physical Sciences Research and Applications Division is conducting basic research in ground laboratories, in drop towers, in parabolic and suborbital flight, and in low Earth Orbit (e.g., on ISS, X37B, and the Russian BION M2). The Cold Atom Laboratory on ISS is an excellent example of a facility that supports SLPSRA basic research. In addition to the non-NASA research being conducted in the ISS National Laboratory, the ISS is also conducting basic research such as the externally-mounted Alpha Magnetic Spectrometer. It is important to maintain a balanced research portfolio, and to ensure that the Agency uses the unique capabilities of ISS to support its deep space exploration efforts, as well as conduct basic research.

Question 13:

What type of workforce skills do you believe will be essential for a lunar program, and a lunar program that would be done on a rapid timescale?

Answer 13:

NASA and its industry partners have all of the workforce skills required for the lunar program from development through operations, even with an accelerated timescale.

Question 13a:

How would you anticipate acquiring and retaining those workforce skills?

Answer 13a:

Please see response to Question #13, above.

Question 13b:

What, if any, challenges or changes might be involved in meeting workforce requirements and how might NASA address them?

Answer 13b:

Please see response to Question #13, above.

Question 14:

Mr. Gerstenmaier testified that NASA would look at "a mixture of approaches depending on the hardware and the systems that we put together" for acquisition of the 2024 lander system. What will be NASA's acquisition strategy for the Gateway and a lunar surface program?

Answer 14:

NASA employs several kinds of mechanisms to work with the commercial sector to advance U.S. space capabilities and to purchase use of such capabilities to meet NASA's requirements. These mechanisms may include – but are not limited to – contracts resulting from competitive procurements to fulfill specific Agency requirements, as well as contracts resulting from the use of competitive acquisition for research and development through the Broad Agency Announcement (BAA) process that will advance NASA mission and program objectives and mature commercial capabilities. These contractual instruments represent just two of the mechanisms NASA employs to encourage commercial innovation while obtaining research and development of technologies that NASA may later acquire use of or ownership to meet mission needs.

The following represents a top-level snapshot summary of recent and near-term acquisition activities for Gateway, Human Landing System, and supporting systems:

- Integrated Human Landing System
  - 11 companies were awarded contracts under NextSTEP BAA Appendix E – Descent Element, Transfer Element, and Refueling for studies and prototypes
  - Multiple industry systems will be developed to support a 2024 lunar landing demonstration mission via contracts to be awarded under NextSTEP BAA Appendix Human Landing Systems

- Gateway
  - May 20, 2019 – NASA released the Request for Proposals (RFP) Synopsis for Gateway Logistics Services May 23, 2019
  - NASA awarded the Power and Propulsion Element (PPE) to Maxar Technologies

- The Gateway platform will include a minimal pressurized habitation module with environmental control and life support systems to house astronauts during lunar missions. In order to meet the Gateway Program's schedule and support the Vice President's 2024 human lunar landing mandate, NASA determined it was necessary to continue to work with Northrop Grumman Innovation Systems for these highly specialized services.

- Refueling Element
  - The study phase for the Refueling Elements is already underway as part of contracts awarded under NextSTEP BAA Appendix E

In the case of the Gateway, on May 23, 2019, Maxar Technologies was awarded a firm-fixed price contract to partner with NASA to develop and demonstrate the PPE element. The PPE BAA, released on September 6, 2018, provided a minimal set of NASA unique requirements allowing industry room to innovate and add their own objectives. The firm-fixed price award includes an indefinite-delivery/indefinite-quantity portion of up to $12 million total for additional identified analyses and risk reduction activities. Maxar will own and operate the PPE during development, launch, and flight demonstration. The flight demonstration will last as long as one year, after which NASA will have the option to acquire the residual post-demonstration in-flight asset for use as the first element of the Gateway.

Question 14a:

What are the criteria for decisions on whether or not systems will be procured through firm-fixed-price, cost-plus, or other acquisition approaches?

Answer 14a:

The particular approaches to be employed in future acquisitions will depend on a variety of factors designed to match the unique circumstances of the procurement with the appropriate acquisition mechanism as well as applicable lessons learned from previous efforts.

Question 15:

Mr. Gerstenmaier testified that NASA does not have a space suit that is "appropriate for the activity for the moon today," but that NASA has "portions of the suit that are sufficient." What portions of the suit does NASA already have and what portions of a suit needed for 2024 still need to be acquired and/or developed?

Answer 15:

NASA is developing a flexible spacesuit architecture with common core subsystems that can be modified to support the needs of specifics destinations from low-Earth orbit to the lunar surface. The Agency plans to conduct a suit demonstration utilizing the new spacesuit architecture optimized for LEO on the ISS in 2022 or 2023 to validate the performance of the exploration Portable Life Support System (PLSS) and rear-entry upper torso assembly.

For the lunar surface, NASA will need a high mobility lower torso assembly, outer protective garments optimized for lunar dust and thermal environments, and as well as some avionics component swaps in the PLSS for lunar environment compatibility.

Question 15a:

How will NASA acquire (e.g., existing contracts, in-house development, or new acquisitions) any portions of the suit that are needed and when?

Answer 15a:

NASA plans to formulate an acquisition strategy for the lunar suits in the months ahead. The ISS demonstration suit is being assembled in-house with individual components acquired from multiple vendors across the country.

Question 15b:

If decisions on suit acquisition have not been made yet, when will they be made?

Answer 15b:

Please see response to Question #15a, above.

Question 16:

Mr. Gerstenmaier testified that NASA is taking the hardware they have already built and has "figured out how to implement that hardware to achieve the lunar goal." What existing hardware, specifically, is NASA using to achieve the lunar goal and under which programs has that hardware been developed?

Answer 16:

NASA's human lunar exploration effort will employ the Space Launch System, Orion crew vehicle, and Exploration Ground Systems funded under Exploration Systems Development. The high power, high throughput SEP spacecraft work begun under the cancelled Asteroid Redirect Mission was leveraged to jump start the Gateway PPE activities. NASA recently awarded a contract to Maxar Technologies to partner with NASA to develop and demonstrate PPE, the first element of the Gateway. Previous investments in spacesuit technology funded under the Game Changing Development Program, Small Business Innovative Research Program, and Advanced Exploration Systems are included in the flexible spacesuit architecture. Beyond this, it is important to note that the lunar program will employ resources developed across the Agency, including the Human Exploration and Operations, Science, and Space Technology mission directorates, to attain its lunar goals.

Question 16a:

How much adaptation of existing hardware would NASA need to carry out in order to make it usable for a potential 2024 landing?

Answer 16a:

The Agency's existing hardware was designed and has been built for deep space exploration, including cislunar flight.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

Keeping Our Sights on Mars: A Review of NASA's Deep Space Exploration Programs and Lunar Proposal

Questions for the Record to:

Mr. Gerstenmaier (NASA)

Submitted by Congressman Bera

Question 1:

Can you please share all of the studies that have been done on the economic return on investment from NASA's Apollo Program?

Answer 1:

Please see attachment, which discusses Apollo impacts and Apollo-era spinoffs.

EDDIE BERNICE JOHNSON, Texas
CHAIRWOMAN

FRANK D. LUCAS, Oklahoma
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 Rayburn House Office Building
Washington, DC 20515–6301
(202) 225–6375
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May 29, 2019

Mr. William H. Gerstenmaier
Associate Administrator, Human Exploration and Operations Mission Directorate
National Aeronautics and Space Administration
300 E Street SW
Washington, DC 20546

On behalf of the Committee on Science, Space, and Technology, I want to express my sincere appreciation for your participation in the May 8, 2019 hearing entitled "*Keeping Our Sights on Mars: A Review of NASA's Deep Space Exploration Programs and Lunar Proposal.*"

I have attached a transcript of the hearing for your review. The Committee's rule pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee, when it is decided they will be printed, shall be published in substantially verbatim form, with the material requested for the record inserted at that place requested, or at the end of the record, as appropriate. Individuals, including Members, whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication. Any requests by those Members, staff, or witnesses to correct any errors other than errors in the transcript, or disputed errors in transcription, shall be appended to the record, and the appropriate place where the change is requested will be footnoted. Prior to approval by the Chair of hearings conducted jointly with another Congressional Committee, a memorandum of understanding shall be prepared which incorporates an agreement for the publication of the transcript.*

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I am also attaching questions submitted for the record by Members of the Committee. Please submit answers to all of the enclosed questions no later than **Wednesday, June 12, 2019**.

All transcript edits and responses to questions should be submitted to me. If you have any further questions or concerns, please contact me at Griffin.Reinecke@mail.house.gov or at (202) 225-6375.

Sincerely,

Kendra S. Horn
Chair
Committee on Science, Space, and Technology
Subcommittee on Space and Aeronautics

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

Keeping Our Sights on Mars: A Review of NASA's Deep Space Exploration Programs and Lunar Proposal

<u>Questions for the Record to:</u>

Mr. Gerstenmaier and Mr. Sirangelo (NASA)

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1. Mr. Gerstenmaier noted on April 30 at the joint Space Studies Board/Aeronautics and Space Engineering Board meeting at the National Academies that the proposed 2024 Moon landing would be "minimalist." How long will the first mission on the lunar surface last? What activities will the astronauts conduct?
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   - When would the second mission occur, and how often would NASA anticipate subsequent missions occurring?

2. Can you explain in clear terms what <u>new</u> risks, if any, NASA is proposing that the U.S. Government and the American people accept in carrying out the 2024 accelerated Moon landing? What, specifically, would NASA do to drive down that additional risk to the lowest possible level?

3. Will the NextSTEP-2 Broad Agency Announcements (BAAs) for the Gateway element architecture provide "significant commercial applications beyond NASA" as stated in NASA's NextSTEP-2 document?
   - What evidence will NASA require of the proposers regarding any commercial lunar market?
   - Will the government own the intellectual property associated with the systems developed under NextSTEP?

4. What is the safety policy associated with Gateway, surface landing, and other capabilities that would be developed under the BAA, and does it apply to government astronauts?
   - If there is an accident, will NASA have immediate access to information on hardware pedigree, certification of parts, qualification of materials, and prior testing and analyses?

5. How is NASA prioritizing sustainability in developing the plans for a 2024 human lunar landing?
    - Will NASA require it in any contracts?
    - Which elements of the 2024 landing (e.g., the initial space suits, a small habitation module, the integrated human lander) would be sustainable or reusable?

6. Will preparation for a lunar field station be included in NASA's amended five-year budget proposal?
    - If yes, what exactly will this lunar field station be and what it will do? Is it envisioned to be robotic, occasionally crewed, or permanently crewed?
    - What is the timeline for a lunar field station?
    - What, if any, entities other than NASA would you anticipate using the lunar field station, and would they be contributing funding to develop it?

7. The Congressionally-directed Mars 2033 report stated that "internal NASA planning documents do not adequately justify why many of the scientific activities that may be conducted on the Gateway could not be performed using solely robotic means." To what extent has the science community determined the relative priority of carrying out science on the Gateway versus science on the International Space Station, or a free-flying spacecraft?

8. How will NASA respond to the Aerospace Safety Advisory Panel (ASAP) recommendation that NASA "immediately" transition to new space suits for space walks outside of the International Space Station?

9. Has NASA made a final decision on whether or not it will proceed with the full Green Run ahead of EM-1? If so, have any changes been made to the original testing content, and why?
    - If not, when will you make the decision?

10. The Congressionally-directed Mars 2033 report indicated that, under the previous 2028 lunar landing plan, NASA would need to begin systems development of a Mars deep space transport spacecraft in 2024 in order for it to be ready for a 2039 human mission to orbit Mars.
    - What timeframe does the current lunar plan assume for a future crewed mission to the surface of Mars?
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11. How would Entry, Descent, and Landing (EDL) technology developed for the lunar surface be useful toward a landing of humans on Mars?
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12. The recent National Academies consensus study report, *A Midterm Assessment of Implementation of the Decadal Survey on Life and Physical Sciences Research at NASA* recommended that NASA adopt a "cautious approach" when shifting and focusing the NASA research portfolio toward more exploration-focused research, because basic research can have major impacts, sometimes unexpected ones, in the long term. How is NASA responding to this recommendation?

13. What type of workforce skills do you believe will be essential for a lunar program, and a lunar program that would be done on a rapid timescale?
    - How would you anticipate acquiring and retaining those workforce skills?
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14. Mr. Gerstenmaier testified that NASA would look at "a mixture of approaches depending on the hardware and the systems that we put together" for acquisition of the 2024 lander system. What will be NASA's acquisition strategy for the Gateway and a lunar surface program?
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HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

Keeping Our Sights on Mars: A Review of NASA's Deep Space Exploration Programs and Lunar Proposal

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Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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WASHINGTON, DC 20515–6301
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www.science.house.gov

May 29, 2019

Mr. Mark Sirangelo
Special Assistant to the Administrator
National Aeronautics and Space Administration
300 E Street SW
Washington, DC 20546

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Sincerely,

Kendra S. Horn
Chair
Committee on Science, Space, and Technology
Subcommittee on Space and Aeronautics

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

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National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001

August 21, 2019

Reply to Attn of: OLIA/2019-00139:SWQ:dac

The Honorable Roger Wicker
Chairman
Committee on Commerce, Science,
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Senator Capito resulting from the May 14, 2019, hearing entitled, "The Emerging Space Environment: Operational, Technical, and Policy Challenges."

This material completes the information requested during that hearing.

Sincerely,

Suzanne M. Gillen
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosure

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

SENATE SUBCOMMITTEE ON AVIATION AND SPACE HEARING ON THE EMERGING SPACE ENVIRONMENT: OPERATIONAL, TECHNICAL AND POLICY CHANGES

MAY 14, 2019

Written Questions Submitted to NASA Administrator Jim Bridenstine

Submitted by Senator Capito

Question 1. Orbital debris has become an increasingly challenging and potentially dangerous obstacles for satellites. With years of space activity and recent events, thousands of small pieces of debris has increased the risk of impacts to the International Space Station (ISS) by an estimated 44 percent over a 10-day period. Administrator Bridenstine, we have talked about this before and most recently in March, but I would like to revisit with you and ask the other panelists about the potential of robotic satellite serving offers in this space.

Can this capability be a tool in our efforts to combat space debris? I am proud of the work being done in West Virginia in this field – on projects such as RESTORE-L – and feel this capability can be a solution.

Answer 1. Restore-L technologies include an autonomous relative navigation system with supporting avionics, and dexterous robotic arms and software. The suite is completed by a tool drive that supports a collection of sophisticated robotic tools for robotic spacecraft refueling, and a propellant transfer system that delivers measured amounts of fuel at the proper temperature, rate, and pressure.

The autonomous relative navigation system is potentially applicable to orbital debris remediation should there be a need to navigate to and approach debris. While the dexterous robotic arms could potentially be applied for active debris removal, the size of the debris would be a limiting factor to its applicability as well as the orientation/tumbling nature of the debris.

Question 2. It is clear that China has significant ambitions over the next 10 to 15 years to develop the capabilities in order to conduct manned lunar missions and set the stage for a new age in space exploration.

You state in your testimony that you expect NASA to meet its deadline of 2024 for NASA's next mission to the Moon (aka Artemis). Could you elaborate on some of the initiatives NASA is undertaking to meet the accelerated deadline?

Answer 2. On March 26, 2019, the Vice President announced at a meeting of the National Space Council in Huntsville, Alabama, that, at the direction of the President of the United States, it is the stated policy of the United States of America to return American astronauts to the Moon within five years and that, when the first American astronauts return to the lunar surface, they will take their first steps on the Moon's South Pole. On May 13, 2019, NASA submitted a revised FY 2020 budget to Congress that would provide a "down payment" of $1.6B to achieve this aim. Our goal is to leverage and build upon our existing work and plans to achieve these new goals.

Schedule performance by the Space Launch System (SLS) and Orion are critical to achieving a human return to the Moon by 2024 with Artemis 3. The Human Exploration and Operations Mission Directorate (HEOMD) completed an assessment of alternate approaches for hardware processing and facilities utilization for key components, with the goal of maintaining an early as possible date for the launch of the uncrewed Artemis 1 mission. The NASA Office of the Chief Financial Officer performed a schedule risk assessment of the Artemis 1 launch date, including the integrated schedule and associated risk factors ahead of Artemis 1. NASA leadership is currently evaluating these results as they consider a new launch date

The Agency is also focusing on completing a minimum-capability version of the lunar Gateway to support the lunar landing of Artemis 3. In this approach, we would begin with the Gateway's Power and Propulsion Element (awarded to Maxar Technologies on May 23, 2019) and a basic habitation capability, which would support the 2024 mission.

For missions to the lunar surface, the current plan is for astronauts to employ a transfer vehicle to travel from the Gateway to low lunar orbit, a descent vehicle to land on the surface of the Moon, and an ascent vehicle to return to the Gateway. The vehicles will be developed by the private sector and procured by NASA. NASA is moving rapidly to support development of these critical pieces of the exploration architecture.

On February 7, 2019, NASA released a solicitation under Appendix E of the second Next Space Technologies for Exploration Partnerships (NextSTEP-2) Broad Agency Announcement (BAA) to seek proposals from industry in support of design analysis, technology maturation, system development and integration, and spaceflight demonstrations for a human lunar landing system. Proposals were received March 25, 2019 and selections were announced on May 16, 2019. The 11 companies selected will conduct studies and undertake preliminary design and development work of prototype components and sub-systems of human lander capabilities for the Artemis lunar exploration program over the next six months. Appendix E is a six-month risk reduction effort including studies and prototype development.

Following the March 26 announcement by Vice President Pence that charged NASA to send humans to the lunar South Pole by 2024, NASA assessed options to expedite the work. Appendix E will continue and will be used to guide NASA's Human Lander System (HLS) requirements, formulation and planning. The HLS capability development and crewed flight demonstration will be competed under a new, full and open solicitation, NextSTEP Appendix H, Integrated Human Landing System. The updated Appendix H pre-solicitation notice was released on April 26, 2019 and signals the Agency's intent, by summer 2019, to seek proposals from industry in support of rapid development and demonstration of integrated human lunar landing systems, including elements such as a descent element, ascent element, and transfer vehicle. NASA will seek proposals from U.S. industry for the development, integration, and crewed demonstration of these elements as a functional human landing system that can fulfill NASA and industry requirements, and meet the challenge to send the next man, and the first woman, to the Moon by 2024.

All of NASA's technical efforts to meet the Artemis 3 deadline of 2024 are dependent upon the Agency receiving the necessary resources in a timely manner. NASA appreciates Congress' consistent support for its exploration efforts, and is ready to provide the information Congress requires for its consideration of this bold new initiative.

Question 3. The ISS can bring down the cost and risk for missions to the Moon and Mars, giving us a head start.

With renewed interest in lunar missions, what technological developments can we do on the ISS that we can use to go back to the moon?

Answer 3. In order to prepare for human expeditions into deep space, the Agency must first conduct breakthrough research and test the advanced technology necessary to keep crews safe and productive on long-duration space exploration missions. NASA plans to continue to use the International Space Station (ISS) as a testbed to fill critical gaps in technologies that will be needed for long-duration deep space missions. For example, elements of the ISS life support and other habitation systems (e.g., oxygen generation and carbon dioxide removal systems) will be evolved into the systems that will be used for deep space exploration missions and undergo long-duration testing. It is NASA's plan to first develop and demonstrate many critical technology capabilities using LEO platforms prior to deploying these capabilities beyond LEO. This approach is much more cost-effective and faster than conducting this research in cislunar space because of the risks inherent in operating so far from the Earth.

NASA is also developing a flexible spacesuit architecture with common core subsystems that can be modified to support the needs of specific destinations from LEO to the lunar surface. The Agency plans to conduct a suit demonstration utilizing the new spacesuit architecture optimized for LEO on ISS to validate the performance of the exploration Portable Life Support System (PLSS). The Agency is currently assessing plans to ensure continued support of both the ISS EVA requirements and the distinct requirements associated with a lunar surface suit. NASA intends to demonstrate the core spacesuit technologies and subsystems applicable to both ISS-based operations and surface exploration through a series of subsystem demonstrations at ISS beginning in 2019 and culminating in delivery of a complete suit system in 2023 for an on-orbit demonstration at ISS prior to the 2024 mission.

Additionally, ISS is necessary to support space biomedical research to mitigate 22 human health and performance risks identified by NASA's Human Research Program to enable safe long-duration ISS missions and future deep space missions. The ISS biomedical research is expanding our capabilities to protect the health and safety of astronauts and include investigations on deep space habitat standards and systems, behavioral health countermeasures, innovative medical technologies for exploration, countermeasures for crew visual changes, space radiation protection, advanced food and pharmaceutical systems, and validation of physiological countermeasures to ensure crew health during extended one-year ISS missions and all phases of future exploration missions.

Question 4. The ISS - and any commercial space station – will be able to serve as a second staging grounds for testing mechanical equipment for further space travel.

If such a transition were to take place – from the ISS to a commercial entity or entities – how could we get around this bottleneck from ground to space flight?

Answer 4. NASA does not anticipate a bottleneck in LEO as commercial opportunities are opened up and realized. The Agency is creating new opportunities for collaboration with industry on the ISS and developing public-private partnerships for exploration systems that will extend human presence into the solar system. As detailed in the 2018 ISS Transition Report,[1] one of the criteria for transitioning away from ISS to a commercial platform or platforms will be the availability and capability of these platforms to meet NASA's LEO requirements. These partnerships will further accelerate the transition of human spaceflight operations in LEO to commercial partners for NASA and non-NASA needs. To support this transition, the ISS will focus near-term activities on supporting commercial industry as well as meeting government requirements, such as exploration research and development, in LEO. In parallel, NASA is creating a focused effort aimed at long-term American operations in LEO independent of the ISS through collaboration with commercial partners.

NASA will have significant requirements for access to LEO in the foreseeable future. These include continued microgravity research as well as accommodations for U.S. crewmembers for training, procedure validation, and proficiency purposes. It is essential that there not be a gap in access to LEO, which is why the Administration's policy is to maintain continuous access to LEO throughout the transition of NASA's funding for its LEO requirements, whether this means transitioning the operations of the ISS to private industry through public-private partnership, augmenting the ISS with privately developed modules, combining portions of the ISS with a new private platform, or beginning anew with a free-flying platform.

Question 5. In addition, what should Congress keep in mind in order to spur competition in LEO (low earth orbit)?

Answer 5. On June 7, 2019, NASA released a number of documents designed to encourage the development of a robust LEO economy, including a policy on the commercial use of ISS, a revised forecast of the Agency's needs in LEO, and a larger strategy for the commercialization of LEO. These and other documents that may be of interest to Congress can be accessed at the newly established web page below.

https://www.nasa.gov/leo-economy/welcome-to-low-earth-orbit-economy

[1] International Space Station Transition Report, March 30, 2018, https://www.nasa.gov/sites/default/files/atoms/files/iss_transition_report_180330.pdf

National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001

March 3, 2020

Reply to Attn of: OLIA/2019-00167:GA:dac

The Honorable Kendra Horn
Chairwoman
Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairwoman Horn:

Enclosed are responses to written questions submitted by you resulting from the June 11, 2019, hearing entitled, ***"Discovery on the Frontier of Space: Exploring NASA's Science Mission."***

This material completes the information requested during the hearing.

Sincerely,

Suzanne Gillen

Suzanne M. Gillen
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosure

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

Discovery on the Frontiers of Space: Exploring NASA's Science Mission

Questions for the Record to:

Dr. Thomas Zurbuchen

Submitted by Chair Kendra Horn

Question 1:

You recently asked your division advisory committees to consider whether NASA is sufficiently able to support science that is multi-disciplinary, interdisciplinary, or high-risk-high-reward. What did they conclude from that effort, and what changes, if any, are you making as a result?

Answer 1:

NASA's Science Mission Directorate (SMD) recognizes the peer review process used to evaluate proposals is perceived to discourage high risk/high reward ideas and seeks to encourage more of these types of proposals. Internal data indicates that approximately 10% of proposals received by SMD are classified as high risk/high reward by peer reviewers, and that these proposals are selected at a higher rate than other proposals. Nevertheless, the perception that SMD is unwelcoming to highly innovative proposals is widespread. SMD is considering the best approach towards increasing the high risk/high reward proposals submitted to its solicitations, either through developing new solicitations or through modifying existing processes to allow proposers to indicate why they feel that their proposal is high risk/high reward and, in the event it is not selected for funding, subjecting the proposal to a further review for special funding.

SMD also recognizes that there is tremendous potential to make revolutionary scientific advances at the interfaces between disciplines and is considering ways to provide opportunities for integrated, interdisciplinary research that encourage collaboration. For example, the on-going collaboration between planetary science and astrophysics has enabled significant progress in the field of exoplanets and serves as a model for how other disciplines might work together in the future. We are expanding that work to include Heliophysics in order to understand the impact of different stellar types on their orbiting planets. Within the Earth Science Division, observations from the flight programs along with the research and analysis programs advance the interdisciplinary field of Earth system science, and the Applied Sciences program facilitates the use of Earth observations and applications among a wide variety of other scientists and stakeholders outside of the Earth Science Division.

Question 2:

Is JWST on track to meet the March 2021 launch date and $8.8 billion development cost cap?

Answer 2:

Yes.

Question 2a:

How much schedule reserve is still available?

Answer 2a:

The Program is performing within the re-planned budget guidelines, and carrying approximately 63 days of schedule margin to the March 2021 launch readiness with 7 days of liens.

Question 2b:

Has NASA conducted the review of the schedule and budget recommended by the GAO in their annual assessment of the mission in March of this year?

Answer 2b:

The GAO schedule and budget review recommendations were met following the Systems Integration Review in September 2019 and were formally part of the Key Decision Point D held in November 2019.

Question 2c:

What are the major milestones the JWST project still has to achieve between now and launch? What do you consider to be the greatest remaining risks?

Answer 2c:

As of January 2020, the remaining major milestones were: Observatory environmental testing (acoustics, sine vibe); final sunshield deploy, fold and stow. Although we have refined models, conducted numerous risk reduction activities, and have lots of experience and test data from the Spacecraft and OTIS element testing, the observatory-level environmental testing is still a first-time activity, and hence, carries some level of risk.

Question 3:

A common tenet reiterated in the decadal surveys is the importance of "balance," and you testified that "maintaining a balanced science program" is one of the "strategic focus areas" of the Science Mission Directorate. How does NASA evaluate whether or not a program or the programs within a division or directorate are balanced? What does "balance" mean, and why is it important? What are the signs a program is in or out of balance?

Answer 3:

NASA's Science Mission Directorate (SMD) strives to maintain a balanced portfolio that enables cutting-edge science from a diverse scientific community, explores new worlds, increases our understanding of the universe, and encourages STEM leadership both today and in the future. A balanced set of programs allows SMD to sustain progress towards our science goals and includes basic research, modeling programs, technology development, missions, mission data analysis, and data and information systems. We accomplish this through a range of mission types, from larger, less frequent, spacecraft missions to smaller missions that can be flown more frequently, many of which are led by principal investigators.

Smaller, less expensive missions generally have more permissive risk postures, and SMD has recently begun an initiative to better define the minimum oversight required for the least expensive missions that should allow proposers to take better advantage of the higher risk tolerance associated with these missions.

SMD relies on review by external advisory committees, both those in the NASA Advisory Council structure as well as the committees of the National Academies of Science, Engineering and Medicine, to ensure that its program is balanced across both subject areas and program types and sizes. Besides reviewing the potential science and technology opportunities of each program and project, these review bodies also evaluate cost and schedule performance, regardless of size and scope, in order to prevent a small number of projects from taking over the portfolio as a whole.

Question 4:

How is NASA balancing the scientific value of proposed Commercial Lunar Payload Services (CLPS) missions against the value for human lunar exploration?

Answer 4:

The CLPS project is led by the NASA Science Mission Directorate and is providing an innovative and cost-effective approach to performing science investigations of the lunar surface. The science investigations that are selected are aligned with the science objectives documented in the science Decadal surveys. Consideration is given to the alignment of the science objectives and the human exploration strategic knowledge gaps, many of which overlap. For example, both the lunar science community and the human exploration strategists and technologists want to find the horizontal and vertical distribution of volatiles on or below the lunar surface. NASA will continue to look for opportunities to fly payloads and conduct science investigations using the CLPS delivery services that align with science objectives and human exploration objectives, while also conducting pure science investigations on separate CLPS delivery missions to locations all across the lunar surface that are of scientific interest.

Question 4a:

Who has the final authority on which missions get approved, and what are the criteria for selection?

Answer 4a:

The NASA Science Mission Directorate selects the instruments and payloads that will fly on the procured CLPS delivery services. The delivery services are not NASA missions. They are delivery services provided by the CLPS commercial landing services providers. As part of the review process, representatives from the Human Exploration and Operations Mission Directorate and Space Technology Mission Directorate are members of the review panel along with scientists. The review panel provides recommendations to the selecting official after all of the proposals have undergone the standard review process. The criteria for selection is based on the standard Announcement of Opportunity (AO) and NASA Research Announcement (NRA) processes that SMD uses to evaluate all proposals.

Question 5 -5c:

What is the role of small satellites (SmallSats) and CubeSats in the Science Mission Directorate (SMD) portfolio?

a. Will SmallSats and CubeSats be one of many platforms that scientists might select in their science proposals?

b. What is NASA spending annually on SmallSats and CubeSats for science or technology demonstration purposes?
c. How will SMD SmallSat and CubeSat activities be managed, and how will the management align with the recommendations from the 2016 National Academies' report, *Achieving Science With CubeSats,* which included a recommendation that NASA "develop centralized management of the agency's CubeSat programs for science and science-enabling technology that is in coordination with all directorates involved in CubeSat missions and programs?"

Answer 5-5c:

The NASA Science Mission Directorate (SMD) has committed to investing about $100 million annually in small spacecraft capabilities, including CubeSats, due to their potential in enabling new science and the opportunity for small spacecraft technology to drive innovation toward mission success. The Directorate is building SmallSat partnerships across disciplines and sectors, and investing in early-stage research and technology through all of its disciplines. All SMD science areas are funding studies and flight missions using EELV Secondary Payload-Class SmallSats to CubeSats as platforms to enable innovative science measurements. Notable scientific and technology firsts have been achieved by NASA through these missions where results have been shared by the scientific community in the journal *Nature* and other leading publications.

Scientists are indeed incorporating SmallSats in their science proposals.

- In NASA's Earth Science Division (ESD), CubeSats are being selected as science payloads under Earth Venture Instrument competitive solicitations. For example, the Cyclone Global Navigation Satellite System (CYGNSS) is an eight-satellite SmallSat constellation that is currently on orbit studying the formation and intensification of tropical cyclones. In 2018, ESD selected the Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE), a two CubeSat mission.
- Also in 2018, NASA's Astrophysics Science Division (ASD) selected nine SmallSat study projects for advanced astronomical space-based measurements.
- In June 2019, NASA's Heliophysics Science Division (HSD) selected two SmallSat constellation missions: the Polarimeter to Unify the Corona and Heliosphere (PUNCH), and the Tandem Reconnection and Cusp Electrodynamics Reconnaissance Satellites (TRACERS).
- Also in June 2019, NASA's Planetary Science Division (PSD) selected three finalist SmallSat missions under the Small Innovative Missions for Planetary Exploration (SIMPLEx) program.

The Agency's technology programs have increased investment in technology validation, through demonstration missions, in order to increase technology readiness and support risk reduction of future missions. This includes programs such as the In-Space Validation of Earth Science Technologies (InVEST) and the Heliophysics Technology Demonstration Mission of Opportunity (H-TIDeS). Additionally, a significant number of existing technology programs are now emphasizing investment in miniaturization of science instruments.

The Earth Science Division is also implementing a Small Satellite Constellation Data Buy pilot program to evaluate how data derived from privately operated small satellites could augment the Agency's Earth observations for the purpose of research and applications. NASA-funded researchers are currently examining data from three providers – Planet, DigitalGlobe, and Spire – to help determine their utility for advancing NASA's science and applications goals. The results of this assessment are expected in early

FY 2020, and will help inform how NASA leverages commercially available data to advance NASA science and applications activities.

With respect to the management strategy, as stated in our August 2017 response letter to the National Academies, NASA believes close coordination – rather than centralized management – is the more effective approach toward advancing its diverse goals. In setting up this coordination process, NASA has continued to focus on communication, coordination, and consistent guidance related to SmallSat/CubeSat activities and processes. NASA's Small Spacecraft Strategic Plan is at the center of our approach to guide coordinated activities among the mission directorates for high-priority science, support to human exploration, disruptive technology innovation, and access to space with SmallSats and CubeSats. This strategy is predicated on the worthiness of SmallSats and CubeSats in advancing the NASA 2018 Strategic Plan goals of Discover, Explore, Develop, and Enable, while accepting higher risk for greater potential scientific gain. SMD established a Small Satellite Working Group (SSWG) to coordinate activities across our four research divisions. The SSWG, in turn, has representation on the NASA-wide Small Satellite Coordination Group (SSCG), which coordinates activities with the Human Exploration and Operations Mission Directorate (HEOMD), including the CubeSat Launch Initiative (CSLI), as well as platform technology projects in the Space Technology Mission Directorate (STMD). Since SMD, HEOMD, and STMD fund SmallSats/CubeSats for different purposes, it would be inappropriate to centralize management as their selection and management needs to remain closely integrated with the organization with budgeting authority. However,.NASA will continually re-assess its management approach as it advances its SmallSat/CubeSat investments.

Question 6:

In his testimony, Dr. Sykes stated that NASA is "hiding proposal costs from review panels" and "funneling Research and Analysis funds uncompeted to NASA center scientists." How does NASA respond to Dr. Sykes' statements?

Answer 6:

NASA SMD relies upon competition among research proposals to ensure the highest science value for taxpayer dollars. Peer reviewers are asked to examine the scientific merit, relevance, and cost reasonableness of proposals. "Cost reasonableness" is interpreted to refer to the balance between the work proposed and the various resources requested. To evaluate this balance, peer reviewers do not need to know participant salaries or benefits or organizational overhead. Focus instead is on science value, including the key question of whether the proposed scientific research can be accomplished with the stated resource levels. NASA's Science Mission Directorate has been redacting salaries, benefits and institutional overheads of all proposal personnel from the proposal copies seen by peer reviewers since the release of Research Opportunities in Earth and Space Science (ROSES) 2016 with no demonstrable reduction in the quality of the science supported.

Science Mission Directorate funding supports research at NASA Centers as well as at external organizations (*e.g.*, universities, non-academic non-profits). Unique among Federal Government science organizations, NASA's internal (civil servant) researchers have traditionally competed for the same funding as external researchers. In 2016, it was determined that because of this competitive-funding model, NASA expends significant resources competing for its own research funding. As a result, NASA civil servant scientists spend large amounts of time writing proposals to perform the research that, in many cases, NASA originally hired them to perform. Moreover, the triennial proposal cycle made it difficult for NASA to fund science-enabling activities and assets that require long-term management and specific expertise.

In response to this determination, NASA embarked on a multi-year pilot program, the Internal Scientist Funding Model (ISFM), to reduce the burden on NASA scientists and more efficiently support their research and science-enabling activities. Research funded through the ISFM process is expected to be strategic, forward-leaning, and distinctive — it should be work that is best led by or performed at a NASA Center and provides value to the broader scientific community. In the current implementation of the ISFM, external (non-NASA) peer review is used to improve planned research and to later evaluate progress of that research. One of the key tenets of the ISFM is that the balance between funding for internal and external researchers be unperturbed by the new approach to funding internal research. An assessment of this neutrality is one of the ten measures of success for the pilot program.

Question 7-7a:

What is the current status of the Ionospheric Connection Explorer (ICON) mission launch date?

a. Are the issues with the Pegasus launch vehicle ones we have seen before, or could have anticipated? What is being done to address the issues with the Pegasus launch vehicle?

Answer 7-7a:

This issue has not been seen on previous Pegasus launch vehicles, and this issue was not anticipated. It appears to have occurred as a result of a complicated set of interactions on the launch vehicle that were not observed on previous Pegasus vehicles. The Pegasus for ICON was modified to minimize the issue and then launched successfully on 10/10/19.

Question 7b:

Is a different launch vehicle an option?

Answer 7b:

A different launch vehicle would have delayed the launch date many more months, potentially more than a year. ICON launched successfully on 10/10/2019 aboard the Pegasus launch vehicle.

Question 8:

Our full Committee Chairwoman Johnson and Ranking Member Lucas sent a letter to the FCC urging a reexamination of the 24 GHz spectrum auction after concerns were raised by NASA and NOAA. How is NASA preparing for and mitigating against potential incursions into protected spectral windows for science?

Answer 8:

The spectrum management environment is dynamic and it continues to be shaped by technological advancements, evolving policy frameworks, and emerging operating requirements, posing both opportunities and challenges for NASA spectrum equities. NASA remains committed to proactively addressing these issues both to meet our own mission requirements and to contribute to policy decisions for the efficient use of this valuable, but limited resource. This includes participation in spectrum repurposing initiatives in response to national policy directives as well as Congressional legislation.

NASA remains engaged in efforts to study the impacts of the 24 GHz spectrum auction to in-band and adjacent-band existing and planned operations, particularly with respect to the compatibility between incumbent passive microwave sounders and future 5G systems. In our response letter to Chairwoman Johnson and Ranking Member Lucas, dated June 27, 2019, we provided additional details on these activities. Through active participation in the ongoing executive branch deliberations we can help protect vital national technological and economic interests enabled both through the advancement of 5G wireless communications and preeminence in weather forecasting.

Question 9:

How is the Science Mission Directorate developing the next generation of mission Principal Investigators (PIs)? What are the challenges and opportunities you see in the PI workforce pipeline?

Answer 9:

NASA's Science Mission Directorate (SMD) relies heavily on the innovation and excellence of the science community to develop new mission concepts that expand our capabilities and grow our portfolio. Based on past success and guidance from the National Academies of Science, Engineering, and Medicine, most NASA missions are initiated by proposals from teams led by PIs. Over the past several years, SMD has observed that the diversity of mission PIs does not reflect the diversity of the broader science community. In order to encourage an infusion of new ideas to ensure continued scientific excellence, SMD is working to provide opportunities that will expand the pool of future mission PIs with input provided by members of the scientific community, in particular observations and feedback from a PI diversity workshop held in Washington, DC in November 2018. More recently, SMD gave a NASA National Colloquium, hosted at the University of Colorado, on writing successful mission proposals in which we shared lessons learned about what makes a proposal successful, common mistakes, and experiences from the point-of-view of both proposers and the NASA selection official. The talk was attended in person by 200+ people and has been viewed online by 2000+ people.

The decision to become a mission principal investigator is often influenced by the experiences a researcher has at the graduate and postdoctoral level, decades before they may be ready to submit a proposal to NASA. There are also multiple pathways to mission leadership, through technical achievement and scientific leadership. Therefore, SMD has developed a long-term strategy to cultivate future PIs from the start of their careers through their first mission proposal. This strategy focuses on three areas: 1) increased awareness of what it means to be a PI and the requirements for that position, 2) inclusion as part of a mission team for early career researchers in order to gain hands-on experience, and 3) investigating the pathways that past PIs have taken in their careers prior to assuming this role.

Question 10-10a:

This past fall, the Science Mission Directorate (SMD) issued a Request for Information (RFI) for an SMD-wide strategic plan for scientific data and computing and held a workshop on the topic

a. Will NASA be releasing any findings or outputs from the RFI and the workshop?

Answer 10-10a:

A summary of the responses NASA received a part of the RFI on the Strategic Plan for Scientific Data and Computing is posted on the SMD public website (https://science.nasa.gov/researchers/science-data).

Question 10b:

When do you anticipate SMD will release a strategy on science data, and what will it cover?

Answer 10b:

In December 2019, NASA SMD released the Strategy for Data Management and Computing for Groundbreaking Science 2019-2024 (available online at https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/SDMWG%20Strategy_Final.pdf), the scope of which encompasses all SMD science data systems, including high-end computing. The strategy will promote more efficient and effective data management across the four science divisions, as well as enable cross-disciplinary discovery and analysis of science data.

Question 11-11a:

At the most recent NASA Advisory Council Science Committee meeting May 21-22, 2019, the Science Mission Directorate (SMD) sought feedback on a draft of a new strategic plan for SMD and a separate lunar science strategy.

a. When will the strategies be released?

Answer 11-11a:

The draft NASA Science Plan was released to the National Academies of Science, Engineering, and Medicine (NASEM) Space Studies Board (SSB) which convened an ad hoc committee, held a two-day meeting in August 2019 to review the plan, and provided feedback to NASA SMD in October 2019. NASA SMD is addressing the feedback now and plans to release the NASA Science Plan in March 2020. The Science Strategy of the Moon was completed in September 2019 and continues to be updated as Artemis continues to be developed. Both documents reflect the revisions contributed by the NAC Science Committee at their May 2019 meeting.

Question 11b:

What role will the strategies serve, and what is their relationship to the decadal survey?

Answer 11b:

Finding answers to profound science questions requires a focus on the scientific priorities identified by the National Academies of Science, Engineering, and Medicine (NASEM) through their decadal surveys and by supporting national priorities in science and exploration. The first strategy specified in the draft NASA Science Plan is therefore to execute a balanced science program based on discipline-specific guidance from the NASEM and the second strategy is to participate as a key partner and enabler in the agency's exploration initiative, focusing on scientific research of and from the Moon, lunar orbit, Mars, and beyond.

The draft NASA Science Plan for 2019-2024 delineates an ambitious program that builds on current activities and drives change in high-priority areas across the entire portfolio. The Science Plan should therefore be thought of as a vision to enable exploration and scientific discovery through innovation, interconnectivity and partnerships, and innovation. The decadal surveys provide discipline-specific guidance whereas the Science Plan speaks to strategies that will enable SMD to implement decadal survey recommendations and respond to national priorities through new and innovative technologies, cross-disciplinary science, and partnership models beyond traditional ways of developing missions.

The role of the draft Science Strategy of the Moon is to achieve decadal survey objectives over a plethora of disciplines, perform all research to NASA Science standards (i.e., competitive selections, open data policy), and enable human exploration, which in turn enables more science. The draft Strategy includes approaches to implement decadal science such as using Commercial Lunar Payload Services (CLPS) contracts to deliver precursor robotics (instruments on and near the Moon); crewed missions that will conduct investigations on the lunar surface (including sampling); and rover and lander capabilities. It also leverages other community documents such as the National Research Council's Scientific Context for the Exploration of the Moon (2007).

Question 11c:

How do decadal surveys and other community consensus documents inform the development of the strategies?

Answer 11c:

Through the decadal survey process, the scientific community provides input on key science drivers and the recommended balance between strategic-scale missions, competitively-selected small and mid-scale missions, technology programs, and research and analysis programs. This guidance is designed to enable lasting leadership by providing focus on the highest priority science questions the Nation should be addressing and highlighting areas of opportunity to grow the scientific community's capabilities. Each SMD division manages their portfolio in accordance with this guidance and progress against the decadal surveys is assessed by NASEM as part of their mid-term reviews.

By comparison, the draft NASA Science Plan for 2019-2024 delineates an ambitious program that builds on current activities and drives change in high-priority areas across the entire portfolio. The decadal surveys provide discipline-specific guidance whereas the Science Plan speaks to strategies that will enable SMD to implement decadal survey recommendations and respond to national priorities through new and innovative technologies, cross-disciplinary science, and partnership models beyond traditional ways of developing missions. As one example, the Science Plan seeks to advance discovery in emerging fields by identifying and exploiting interdisciplinary opportunities between traditional science disciplines. The on-going collaboration between planetary science and astrophysics has enabled significant progress in the field of exoplanets, and emerging opportunities exist to use the Earth as a laboratory in support of habitability and heliophysics scientific questions.

Regarding the draft Science Strategy of the Moon, the science goals therein were driven by community-produced documents, including 1) the NASEM 2013 Decadal Survey: Vision and Voyages for Planetary Sciences in the Decade 2013-2022, 2) the National Research Council 2007 Report: The Scientific Context for the Exploration of the Moon, 3) the Lunar Exploration Analysis Group (LEAG) Advancing Science of the Moon report, and the NASA strategic knowledge gaps (SKGs) (i.e., explore the history of the Solar System using the Moon, explore processes that shape planetary bodies, use the Moon as a platform for novel and unique measurements, study of lunar volatiles and explore the utility of lunar resources for exploration and beyond). The draft Strategy also includes efforts to engage the community further to develop ideas for science to conduct on the lunar surface. Regarding recent feedback on NASA priorities for achieving lunar science and exploration goals, in February 2019, the Committee on Astrobiology and Planetary Science (CAPS) released two reports that provided findings and conclusions. CAPS concluded that the NASA Lunar Discovery and Exploration Program (LDEP) is aligned with the decadal priorities and the portfolio "is a welcome development that has the potential to greatly benefit lunar science and could evolve into a program with large science return."

Question 12-12a:

You recently decided to cancel the Interior Characterization of Europa using Magnetometry (ICEMAG) instrument in development for the Europa Clipper mission and instead move forward with a simpler magnetometer instrument managed by NASA. It is my understanding that the decision was made after a termination review, and that a new mechanism to monitor costs on PI instruments flagged cost growth on ICEMAG.

a. What, in concrete terms, does the cost-monitoring mechanism do, and how is it being used?

Answer 12-12a:

As a result of continued, significant cost growth and remaining high cost risk, the ICEMAG investigation on the Europa Clipper mission was terminated. NASA is developing a simpler magnetometer with both the fluxgate sensors and boom under the direction of an integrated product manager, has appointed a world renowned magnetometry expert (Dr. Margaret Kivelson, UCLA) as the science team lead, and has retained all ICEMAG Co-Investigators.

Instruments on flagship missions have a long history of cost growth; this process was put into place for Clipper to monitor instrument cost growth in much more detail before it is too late to take corrective action. Before cost margin is completely utilized, descopes or other options are carefully considered by the Project Manager and NASA HQ.

Question 12b:

Are you using it on missions other than Europa Clipper?

Answer 12b:

NASA is considering this process, possibly with some modifications, to be used on other large strategic missions. This can be codified after Clipper experience and lessons learned are realized.

Question 12c:

How have or will you evaluate this mechanism's success as an effective tool for managing cost?

Answer 12c:

NASA currently is gathering lessons on how this new process is working on Europa Clipper, including intended and unintended consequences, which will be used to refine the process. If SMD determines that the process was successful overall, it may be applied to other large strategic missions. If a sufficient database on instrument cost performance is built, SMD will be able to tell if this new strategy is an effective tool for managing cost.

Question 13:

During the question and answer session of the hearing, Congressman Beyer asked you whether or not NASA scientists were going to be required to debate the credibility of the National Climate Assessment, as was reported in Scientific American on June 7, 2019. You responded that you could provide additional information for the record. Will NASA scientists be required to debate the credibility of the National Climate Assessment or otherwise play a role in the White House review of the interagency National Climate Assessment?

Answer 13:

In March, the White House asked the NASA Deputy Administrator to provide "internal scientific peer review of previously published United States Government assessments of climate change and its national security implications." NASA used the opportunity to revisit and evaluate three recent major national assessments of climate change and national security, including the Fourth National Climate Assessment (NCA4), the ODNI Worldwide Threat Assessment, and the Report on Effects of a Changing Climate to the Department of Defense. Drawing on the wealth of Earth science and climate change expertise at NASA Headquarters, NASA responded with detailed internal peer review comments on the three reports.

NASA responded that it has high confidence in the process through which the NCA4 volumes were produced. NASA is a full member and active participant in the interagency U.S. Global Change Research Program, which, under the Global Change Research Act of 1990, facilitates, manages, and publishes the NCA. For the development of the most recent NCA4, completed in November 2018, NASA data, models, and research were integral inputs, and NASA scientists were actively engaged in the drafting and development of the assessment report during its entire production lifecycle, including seeking and acquiring NASA agency approval of the final report. The list of coordinating lead authors, lead authors, review editors and contributing authors demonstrates contributions from many of the most reputable and accomplished scientists working in climate science today. Report findings were based on scientific, peer-reviewed research, and each source of information utilized was subjected to a quality assurance test including the factors of utility, transparency, objectivity, and integrity. They were rigorously reviewed multiple times by experts, including federal and non-federal scientists, the National Academies, and the public. Review editors ensured that all comments resulting from those reviews were fully addressed and formally dispositioned, resulting in reports that meet the rigorous standards pertaining to highly influential scientific products of the federal government, in accordance with the Information Quality Act.

Question 14-14a:

The Sun is expected to reach its next solar maximum in 2024, the administration's new target for humans returning to the surface of the Moon. What do we know about the space weather environment at the Moon during solar maximum?

a. Do you have any concerns about a Moon landing with humans during a solar maximum?

Answer 14-14a:

There are two primary sources of space radiation that require attention relevant to protecting humans as they land on the Moon. They are Galactic Cosmic Rays (CGR) and Solar Energetic Particles (SEP).

Galactic cosmic rays are high energy charged particles from outside the Heliosphere and are the major long-term radiation threat to astronaut's health, and therefore to human space exploration. During solar maximum, because of the increasing strength of the interplanetary magnetic field, the heliosphere provides a more effective shield against galactic cosmic rays. During solar maximum, the flux of galactic cosmic rays is reduced by as much as 50 percent with respect to the solar minimum, depending on particle energy.

Solar energetic particles are generated by coronal mass eruptions and solar flares that are more prevalent during the solar maximum, but may occur at any time. Astronauts on the Moon's surface and in lunar orbit do not have the protection of the Earth's magnetic field and atmosphere, and are at risk of serious radiation exposure should a large solar energetic particle event occur. For the protection of astronauts, a system must be in place to predict, detect, and mitigate hazards of solar energetic particle events.

Question 14b:

What do we need to learn to best protect astronauts from the radiation risks of a solar maximum event?

Answer 14b:

Learning and understanding the dominant mechanism for producing space weather radiation is first step to mitigating the risks to astronauts. Only then can an effective prediction capability be established to protect human explorers in the lunar environment in advance of occurrence of solar particle events. Currently we have only minutes of advanced warning after detection of a solar eruption. Based on our current understanding, we have predictive tools that generate estimates of the likelihood of all clear conditions. Further investigations with missions and modeling of solar energetic particle events will improve our ability to predict their occurrence and thus the capability to signal "all clear" conditions with high confidence and with greater time in advance, during which astronauts are safe from these risks.

EDDIE BERNICE JOHNSON, Texas
CHAIRWOMAN

FRANK D. LUCAS, Oklahoma
RANKING MEMBER

Congress of the United States

House of Representatives

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July 1, 2019

Dr. Thomas Zurbuchen
Associate Administrator, Science Mission Directorate
National Aeronautics and Space Administration
300 E Street SW
Washington DC 20515

Dear Dr. Zurbuchen:

On behalf of the Committee on Science, Space, and Technology, Subcommittee on Space and Aeronautics, I want to express my sincere appreciation for your participation in the June 11, 2019 hearing entitled "Discovery on the Frontiers of Space: Exploring NASA's Science Mission."

I have attached a transcript of the hearing for your review. The Committee's rule pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee, when it is decided they will be printed, shall be published in substantially verbatim form, with the material requested for the record inserted at that place requested, or at the end of the record, as appropriate. Individuals, including Members, whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication. Any requests by those Members, staff, or witnesses to correct any errors other than errors in the transcript, or disputed errors in transcription, shall be appended to the record, and the appropriate place where the change is requested will be footnoted. Prior to approval by the Chair of hearings conducted jointly with another Congressional Committee, a memorandum of understanding shall be prepared which incorporates an agreement for the publication of the transcript.*

Transcript edits, if any, should be submitted by **July 15, 2019**. If no edits are received by the above date, I will presume that you have no suggested edits to the transcript.

I am also attaching questions submitted for the record by Members of the Committee. Please submit answers to all of the enclosed questions no later than **July 15, 2019.**

All transcript edits and responses to questions should be submitted to Griffin Reinecke. If you have any further questions or concerns, please contact Griffin Reinecke at (202) 225-6375.

Sincerely,

Kendra S. Horn

Kendra S. Horn
Chairwoman
Subcommittee on Space and Aeronautics

Enclosure: Transcript
Attachment: Questions for the Record

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

Discovery on the Frontiers of Space: Exploring NASA's Science Mission

Questions for the Record to:

Dr. Thomas Zurbuchen

Submitted by Chairwoman Kendra Horn

1. You recently asked your division advisory committees to consider whether NASA is sufficiently able to support science that is multi-disciplinary, interdisciplinary, or high-risk-high-reward. What did they conclude from that effort, and what changes, if any, are you making as a result?

2. Is JWST on track to meet the March 2021 launch date and $8.8 billion development cost cap?
    a. How much schedule reserve is still available?
    b. What are the major milestones the JWST project still has to achieve between now and launch? What do you consider to be the greatest remaining risks?

3. A common tenet reiterated in the decadal surveys is the importance of "balance," and you testified that "maintaining a balanced science program" is one of the "strategic focus areas" of the Science Mission Directorate. How does NASA evaluate whether or not a program or the programs within a division or directorate are balanced? What does "balance" mean, and why is it important? What are the signs a program is in or out of balance?

4. How is NASA balancing the scientific value of proposed Commercial Lunar Payload Services (CLPS) missions against the value for human lunar exploration?
    a. Who has the final authority on which missions get approved, and what are the criteria for selection?

5. What is the role of small satellites (SmallSats) and CubeSats in the Science Mission Directorate (SMD) portfolio?
    a. Will SmallSats and CubeSats be one of many platforms that scientists might select in their science proposals?
    b. What is NASA spending annually on SmallSats and CubeSats for science or technology demonstration purposes?
    c. How will SMD SmallSat and CubeSat activities be managed, and how will the management align with the recommendations from the 2016 National Academies' report, *Achieving Science With CubeSats,* which included a recommendation that NASA" develop centralized management of the agency's CubeSat programs for

science and science-enabling technology that is in coordination with all directorates involved in CubeSat missions and programs?"

6. In his testimony, Dr. Sykes stated that NASA is "hiding proposal costs from review panels" and "funneling Research and Analysis funds uncompeted to NASA center scientists." How does NASA respond to Dr. Sykes' statements?

7. What is the current status of the Ionospheric Connection Explorer (ICON) mission launch date?
    a. Are the issues with the Pegasus launch vehicle ones we have seen before, or could have anticipated? What is being done to address the issues with the Pegasus launch vehicle?
    b. Is a different launch vehicle an option?

8. Our full Committee Chairwoman Johnson and Ranking Member Lucas sent a letter to the FCC urging a reexamination of the 24 GHz spectrum auction after concerns were raised by NASA and NOAA. How is NASA preparing for and mitigating against potential incursions into protected spectral windows for science?

9. How is the Science Mission Directorate developing the next generation of mission Principle Investigators? What are the challenges and opportunities you see in the PI workforce pipeline?

10. This past fall, the Science Mission Directorate (SMD) issued a Request for Information (RFI) for an SMD-wide strategic plan for scientific data and computing and held a workshop on the topic
    a. Will NASA be releasing any findings or outputs from the RFI and the workshop?
    b. When do you anticipate SMD will release a strategy on science data, and what will it cover?

11. At the most recent NASA Advisory Council Science Committee meeting May 21-22, 2019, the Science Mission Directorate (SMD) sought feedback on a draft of a new strategic plan for SMD and a separate lunar science strategy.
    a. When will the strategies be released?
    b. What role will the strategies serve, and what is their relationship to the decadal surveys?
    c. How do decadal surveys and other community consensus documents inform the development of the strategies?

12. You recently decided to cancel the Interior Characterization of Europa using Magnetometry (ICEMAG) instrument in development for the Europa Clipper mission and instead move forward with a simpler magnetometer instrument managed by NASA. It is my understanding that the decision was made after a termination review, and that a new mechanism to monitor costs on PI instruments flagged cost growth on ICEMAG.
    a. What, in concrete terms, does the cost-monitoring mechanism do, and how is it being used?

    b. Are you using it on missions other than Europa Clipper?
    c. How have or will you evaluate this mechanism's success as an effective tool for managing cost?

13. During the question and answer session of the hearing, Congressman Beyer asked you whether or not NASA scientists were going to be required to debate the credibility of the National Climate Assessment, as was reported in Scientific American on June 7, 2019. You responded that you could provide additional information for the record. Will NASA scientists be required to debate the credibility of the National Climate Assessment or otherwise play a role in the White House review of the interagency National Climate Assessment?

14. The Sun is expected to reach its next solar maximum in 2024, the Administration's new target for humans returning to the surface of the Moon. What do we know about the space weather environment at the Moon during solar maximum?
    a. Do you have any concerns about a Moon landing with humans during a solar maximum?
    b. What do we need to learn to best protect astronauts from the radiation risks of a solar maximum event?

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

Discovery on the Frontiers of Space: Exploring NASA's Science Mission

Questions for the Record to:

Dr. Thomas Zurbuchen

Submitted by Representative Katie Hill

1. What is the strategy for a Mars Sample Return mission, and what is NASA currently working on toward such a mission?
    a. What is NASA currently spending annually on Mars Sample Return, and what will a Mars Sample Return mission cost in total?
    b. When do you anticipate a Mars Sample Return mission would be launched? What are the limiting factors in determining that date?

2. Since Fiscal Year (FY) 2017, Congress has directed NASA to launch Europa Clipper on the Space Launch System in annual appropriations legislation, and the FY 2019 legislation directs that launch to occur in 2023. How would the administration's new plans to send humans to the lunar surface by 2024 affect NASA's ability to comply with the law?
    a. You testified that using a commercial launcher would "add 3 to 5 years or so of transit time" for the Clipper spacecraft to reach Europa, which would increase the cost of the overall science team and also potentially require design changes of the spacecraft. What would the estimated added cost to the science team and from design changes compare to the cost savings of procuring a commercial launch vehicle?

Senate Committee on Commerce, Science, and Transportation

"Moon to Mars: NASA's Plan for Deep Space Exploration."

Senator Edward J. Markey

Written Questions Submitted by Hon. Edward J. Markey to Jim Bridenstine:

Question 1a: NASA has reportedly contracted with Idaho National Laboratory (INL) for a study evaluating the pros and cons of using highly enriched uranium (HEU) or low-enriched uranium in a space nuclear fission reactor. Please provide the following information on the study:

Who is leading this effort at INL and which other organizations, if any, are involved?

Answer 1a: NASA has initiated a preliminary design study with the Department of Energy to identify options for a lunar surface fission power system with extensibility to Mars. That study will include an assessment of the potential reactor fuel forms and fuel enrichment levels based on the NASA requirement to provide long-duration electric power on the Moon and Mars. It is expected that DOE will solicit assistance from the various DOE National Labs to perform the study.

Question 1b: What specifically are the scope and parameters of the study?

Answer 1b: NASA is still formulating the requirements for the design study, but NASA anticipates seeking designs for a system that can (1) generate about 10 kW-electric and (2) can be developed in time to support a demonstration mission in the mid to late 2020s. Additionally, the total mass and volume of the system must be accommodated by lunar landers that would be available in that same timeframe.

Question 1c: When is it due and will you commit to providing Congress with a copy?

Answer 1c: The due date for a final study presentation is still being negotiated. When the study is complete, NASA will share the results with Congress.

Question 2. Did Congress explicitly authorize funding for the development and recent testing of an HEU-fueled surface-power space nuclear reactor? Please provide details on the funding source within NASA's budget for this specific effort.

Answer 2: The Kilopower project was began in 2015 with the objective to design, build, and test a 1 kW-class fission power system with technology that is extensible up to 10 kW. The Kilopower project culminated in March 2018 with a successful nuclear system test of a prototype HEU reactor with Stirling power converters at the Nevada National Security Site through a partnership with the DOE National Nuclear Security Administration. The Kilopower project demonstration was funded within the Space Technology budget account, and detailed in the NASA budget justification submitted to Congress.

The authorization to conduct this type of technology development effort is in accordance with the Atomic Energy Act of 1954, as amended, and the Department of Energy Organization Act.

Question 3: A moderated reactor design in which the chain reaction is mediated by low-energy neutrons is more complicated to design than the Kilopower

reactor, but it could be more compact than a fast-neutron LEU design. SNAP-10A, the only reactor that the US has launched into space, was a moderated system. Does NASA's research and development program for kilowatt-range surface-power systems also include an effort to design and test a moderated system, in addition to the recently tested fast-neutron Kilopower reactor?

Answer 3: Consistent with both the National Space Policy[1] and the National Space Transportation Policy,[2] NASA leverages DOE expertise in identifying and recommend the preferred reactor design approach, as it did in developing the prototype reactor used in the recent Kilopower test. DOE will consider a broad range of viable reactor options and provide recommendations on a reactor design that meets NASA's mission requirements and can be delivered on schedule with reasonable development risk and cost.

Question 4: The Los Alamos and Idaho National Laboratories both specialize in fast-neutron reactors. Has NASA asked Oak Ridge National Laboratory or another organization that has more experience with slow-neutron reactors to compete for its space reactor project? Please describe in detail how NASA selected the entities involved in this study.

Answer 4: NASA depends on DOE to determine the appropriate National Labs that are best suited to support the study effort. It is anticipated that multiple National Labs will be utilized based on their individual areas of expertise.

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[1] Page 8, Space Nuclear Power.

[2] Page 6, Space Transportation Technology Development

Senate Committee on Commerce, Science, and Transportation

"Moon to Mars: NASA's Plan for Deep Space Exploration."

Senator Gary Peters

Written Questions Submitted by Hon. Gary Peters to Jim Bridenstine:

Question 1: I recently learned about an American Veteran Owned Small Business capable and eager to compete for NASA contracts to provide services currently being outsourced to foreign firms on a non-competitive basis. However, I am concerned about the use of international agreements that result in sole-source awards of large contracts to foreign owned companies. Does NASA have a policy to help ensure American companies can compete for service contracts against foreign sources? Will you commit to working with me to ensure American companies be allowed a fair opportunity to compete for taxpayer funded contracts rather than awarding sole-source contracts to foreign entities?

Answer 1: Contracts with foreign entities comprise a small minority of NASA awards for services and goods to meet mission requirements. Approximately 1.1% of NASA awards are performed outside of the United States. NASA follows the Federal Acquisition Regulation (FAR) for the execution of its contract awards, as well as all other federal laws and regulations that may apply to a specific procurement action. The majority of NASA contracts are conducted on the basis of full and open competition. In certain specific circumstances, 41 U.S.C. 253(c) and 10 U.S.C. 2304(c) authorize Federal agencies to contract without providing for full and open competition. The criteria and procedure for doing so are set forth in the Subpart 6.3 of the Federal Acquisition Regulation (FAR). This FAR Subpart details the specific applications and limitations that guide the use of a sole source contract award. A NASA award of contract to a foreign entity on a basis other than full and open competition under the FAR is infrequent and an exception to the Agency norm. In the case of subcontracts, the FAR provides guidance for the conduct of awards by U.S. government contractors on a competitive basis to the maximum extent practicable consistent with the objectives and requirements of the contract.

NASA complies with all Federal laws and regulations concerning the procurement of goods and services from foreign services, which is reflected in clauses included in many of its contracts. Where appropriate, these clauses flow down to subcontractors as required by the FAR. NASA's commitment to achieving the best possible value for the U.S. taxpayer as it fulfills the requirements of its missions is reflected in the Agency's contract portfolio, approximately 98.9% of which is performed within the United States.

Question 2: The Department of Defense helped establish the Detroit-based Lightweight Innovations for Tomorrow (LIFT) institute. LIFT is a regional public-private partnership—with members from 25 states—that will contract on more than $100 million in R&D to develop and deploy lightweight manufacturing technologies. Lightweight materials are obviously critical for Moon and Mars operations. Separately, Congress has authorized NASA to create an advanced materials and manufacturing technology program for aeronautics. As an advocate of government efficiency, I'd hope NASA would take a look at existing opportunities such as LIFT to build on existing partnerships. Will you work with me to help ensure you are not reinventing the wheel here in establishing a new separate advanced materials program?

Answer 2: We appreciate the need for government efficiency and actively look for opportunities to leverage existing efforts. Both the LIFT Institute and the manufacturing initiative cited in the Aeronautics Innovation Act are focused on advancing manufacturing lightweight materials for aerospace applications. However, they are focused on different types of materials, each of which have specific and unique manufacturing processes and challenges. The LIFT institute is a Department of Defense-sponsored consortium formed to advance lightweight metals manufacturing. NASA is currently developing our future materials and structures research strategy focused on advanced composites, based on outcomes from NASA's Advanced Composites Project (ACP), NASA's Vision 2040 materials study, and consultation with key stakeholders. NASA remains committed to learning from, and potentially leveraging, the public-private partnerships sponsored by other federal agencies, and will leverage insights and lessons learned from establishing the LIFT Institute as appropriate to inform future activities.

Question 3: I am proud that NASA recently announced Detroit-based Futuramic as its Supplier of the Year for working round-the-clock to help NASA speed up the production of the SLS rocket's massive core stage and meet NASA's new expedited timeline. I've visited their facilities [with Astronaut Charles Precourt] and seen the incredible work they're doing to help build the most powerful rocket in history. How do you see NASA leveraging the manufacturing capabilities of places like the Midwest to help us achieve this next great human milestone?

Answer 3: The SLS and Orion programs have made extensive investments in advanced manufacturing techniques like reaction friction stir welding and additive manufacturing – investments to help achieve a production capacity capable of conducting a sustained human space exploration program, help position the U.S. and U.S. companies as world leaders in this critical technological area. Through the Artemis program, the next American Moon walkers will inspire a new generation and bring about new opportunities for companies across the United Sates.

Futuramic, a company with factories in Detroit and Warren, is one of more than 78 Michigan companies and 3,200 businesses across 50 states supporting NASA's return to the Moon by supplying parts for the SLS, Orion spacecraft, and Exploration Ground Systems.

In May 2019, Futuramic delivered a new tool to help NASA speed up production of the SLS rocket's core stage. This tool holds the 130-foot-long, liquid hydrogen tank – the largest part of the core stage – in a stable position, so it can be moved and connected to the upper part of the rocket's core stage, which was completed earlier this year.

The engine section will be the last piece connected to form the entire stage. Tools like this, and another provided by Futuramic earlier this spring to allow more people to work on the rocket's production at the same time, are helping NASA accelerate final integration and assembly of the stage.

Question 4: You talked about the growing and important role of commercial companies in safely and promptly achieving NASA's goals, including Artemis. Unfortunately, the Commercial Space Federation has indicated that the FAA's new proposed licensing rules contain serious flaws that among other things could delay commercial launches needed for Artemis. Are you aware of their concerns and are you relaying those concerns to the Space Council and the Department of Transportation?

Answer 4: Commercial launch service providers have not specifically made NASA aware of any concerns. NASA recommends that the Commercial Spaceflight Federation contact the Federal Aviation Administration (FAA) with any concerns they may have regarding the FAA's proposed new rules.

Question 5: In your testimony you mention in situ resource acquisition. China has announced plans for building a structure on the Moon using in situ resources. Can you share more about our plans for this and how far we are in developing our abilities for this?

Answer 5: The practice of in-situ resource utilization (ISRU) could increase safety and affordability of future human spaceflight missions by limiting the need to launch supplies, such as oxygen and water, from Earth. NASA issued Appendix D of the Next Space Technologies for Exploration Partnerships-2 (NextSTEP) Broad Agency Announcement on Dec. 4, 2017. With it, the Agency sought three areas of work focused on producing propellant and other exploration mission consumables using water from extraterrestrial soils and carbon dioxide from the Martian atmosphere.

- The first track was for one-year studies to identify technology gaps associated with ISRU, and to further define the benefits of including it in space mission architectures.
- The second and third tracks addressed technology development and demonstration for as long as three and a half years. Component-level development and testing in simulated space environments is the focus for Track 2.
- The third track included extensive subsystem development and testing in simulated space environments.

In May 2018, NASA selected 10 companies to conduct studies and advance technologies to collect, process and use space-based resources for missions to the Moon and Mars. NASA placed a special emphasis on encouraging the responders to find new applications for existing, terrestrial capabilities that could result in future space exploration capabilities at lower costs. As with most NextSTEP contracts, the companies involved must include corporate contributions to the overall effort, a measure that boosts private-sector interests in the space economy.

The Space Technology Mission Directorate (STMD) Lunar Surface Innovation Initiative (LSII) aims to spur the creation of novel technologies needed for lunar surface exploration and accelerate the technology readiness of key systems and components. These capabilities are essential for humans and systems to successfully live and operate on the lunar surface. LSII will focus on six primary lunar technology areas, including ISRU, Surface Excavation and Construction, Sustainable Power, Extreme Access and Environment, and Lunar Dust Mitigation. These activities span the Technology Readiness Level pipeline and are developed through a purposeful, integrated strategy which is aligned with the Agency mission architecture.

With NASA's return to the Moon, STMD LSII is working to target key ISRU capabilities which will ensure an early presence on the lunar surface and enable the collection, processing, storing, and use of materials found or manufactured on the lunar surface. These capabilities will allow for Surface Excavation and Construction technologies that enable reliable, remote and/or autonomous manipulation of lunar surface materials for mining, manufacturing and/or construction (e.g., of a habitat, landing pad, berm, or shielding). Additionally, STMD is managing the 10 ISRU NextSTEP public/private partnership contracts which will help lay the foundation for sustainable lunar presence.

Question 6: The only automobile to transport humans on another celestial body was first conceived by a University of Michigan professor [and consultant to the U.S. Army Tank-Automotive Command's (TACOM's) Land Locomotion Laboratory at the Detroit Arsenal in Warren, Michigan]. General Motors of course, later partnered with Boeing to build the Lunar Rover. Can you provide an update on NASA's plans for vehicles to transport astronauts on the Moon and Mars?

Answer 6: NASA aims to create a sustainable deep space infrastructure that will enable access to any part of the Moon as needed. The specifics of potential future Artemis elements, such as pressurized or unpressurized rovers for transporting astronauts across the lunar surface, will be determined as we move forward.

In the area of robotic rovers, NASA recently announced the latest opportunity for industry to participate in its Commercial Lunar Payload Services (CLPS) efforts to deliver science and technology payloads to and near the Moon. The newest announcement calls for companies to push the boundaries of current technology to support the next generation of lunar landers that can land heavier payloads on the surface of the Moon, including the South Pole. These payloads could include rovers, power sources, science experiments, and technology to be infused into the Artemis program.

Senate Committee on Commerce, Science, and Transportation
"Moon to Mars: NASA's Plan for Deep Space Exploration."

Senator Jackie Rosen

Written Questions Submitted by Hon. Jackie Rosen to Jim Bridenstine:

Women in Space and STEM. With the Artemis program, NASA will put the first woman on the Moon. Incredible women at NASA have paved the way for more women in space, but we still have a huge gap in representation. I have legislation – the Building Blocks of STEM Act – which would focus on giving our kids, and especially our girls, the opportunities to explore STEM-related fields from an early age. Research has shown it is critical to offer STEM opportunities and workforce development at an early age, especially to research historically underrepresented groups. Of those students who eventually work in the Aerospace and Defense workforce, 71% of young professionals report they first became interested in these careers during their grade school years.

Question 1: What are other investments Congress should be considering to ensure that today's school-children are well equipped to lead our space exploration workforce?

Answer 1: NASA has a long history of engaging students in its mission. The scope of STEM Engagement encompasses all endeavors agency-wide to attract, engage and educate students and to support educators, educational institutions and professional organizations. STEM Engagement is comprised of a broad and diverse set of programs, projects, activities and products developed and implemented by HQ functional Offices, Mission Directorates and Centers.

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

NASA actively supports the National Science and Technology Council's Committee on STEM Education endeavors, with NASA Administrator Bridenstine serving as the Committee's Co-Chair. The Committee's December 2018 report, *Charting a Course for Success: America's Strategy for STEM Education**, lays out the Federal Government's role in furthering STEM education by working with state, local, education, and American employer stakeholders to build a STEM-proficient citizenry, create a STEM-ready workforce and remove barriers to STEM careers, especially for women and underrepresented groups. Congressional support for the goals, pathways and objectives in this plan is essential to ensuring that all Americans have lifelong access to high-quality STEM education, thereby ensuring that the United States will continue to be the global leader in STEM literacy, innovation and employment.

* The report is available here: https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf

Question 2. I know that NASA has many programs and initiatives aimed at breaking down barriers to girls and underrepresented minorities in STEM. Can you detail some of these?

Answer 2: NASA Offices, Mission Directorates, Centers and Facilities collaborate to provide unique NASA experiences to students, educators, communities, and institutions, as well as streamlined access to NASA content, websites, people, resources, and facilities.

Building a strong STEM workforce for the 21st century and beyond requires the development of a strong and diverse pipeline for STEM, including women and individuals from other underrepresented and underserved groups. NASA develops and delivers activities that support the growth of the Agency's and the Nation's STEM workforce, help develop STEM educators, engage and establish partnerships with institutions, and inspire and educate the public.

Diverse STEM engagement activities inspire, engage and educate girls and underrepresented minorities in STEM. Specifically, The INSPIRE Women Act (P.L. 115-7) directed NASA to encourage women and girls to study STEM and to pursue STEM careers. NASA's efforts in this area span across the scope of NASA's endeavors in public engagement and education, with a focus on mentorship and opportunities that provide all students, including young women and girls, with experiences interacting with NASA's women in action. NASA endeavors to provide unique opportunities for K-12, undergraduate and graduate students to be exposed to STEM through a spectrum of engagement. Activities that reach the targeted demographic, while fulfilling a broader purpose, include:

- NASA astronaut appearances,
- Speakers Bureau, Girls & Boys mentoring opportunities,
- Aspire to Inspire website, and
- Summer Institute in Science, Technology, Engineering and Research
- Science Mission Directorate Science Activation projects, including:
    - Local and community-based Earth science materials, focused for Alaska, the Pacific Northwest, Southwest and Northeast regions, that are culturally respectful
    - Creation of space science-related materials and training, primarily for Girl Scouts
    - Community college/physics activities in Appalachian states

Going forward, NASA educational outreach activities will continue to leverage the Agency's unique mission of research and discovery as a powerful context for inspiration and student learning, sharing our inspirational activities with the broadest audience possible. To this end, NASA will continue to monitor its efforts to share the STEM message with diverse groups, including women and individuals from underrepresented and underserved groups, pledging to use these results as a stepping stone for more effective STEM outreach efforts. Additionally, NASA will continue to work toward attracting and retaining diverse employees in STEM career fields while also providing student access to NASA's world-class research and technology facilities, mission data and Agency technical experts.

Through Minority University Research and Education Project (MUREP), NASA provides financial assistance via competitive awards to Minority Serving Institutions (MSI), including Historically Black Colleges and Universities, Hispanic Serving Institutions, Asian American and Native American Pacific Islander Serving Institutions, Tribal Colleges and Universities, and eligible community colleges. These institutions recruit and retain underrepresented and underserved students, including women and girls, and persons with disabilities, into STEM fields. MUREP investments assist faculty and students in research and provide authentic STEM engagement opportunities related to NASA missions.

Use of Commercial Technology. Much of the necessary technology and infrastructure needed to return to the Moon does not yet exist. For example, NASA plans to extract resources from the lunar surface. Engineers will need to figure out how to turn frozen water locked in the Moon's surface into drinkable water, breathable oxygen, and usable rocket fuel. In order to solve these problems, when possible, NASA can procure products or services from commercial companies to foster growth in the domestic space industry. NASA has long invested in the development of commercial services – in fact, since the beginning of the ISS commercial resupply and crew transportation programs, the United States' share of the global commercial launch market has gone from 0 percent in 2011 to 54 percent in 2017.

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

Answer 1. Nearly every aspect of the Artemis program includes contracts with commercial companies. In certain instances, NASA is pursuing fixed-price commercial service procurement models with the objective of lowering costs and increasing innovation through the engagement of new industrial partners. For example, NASA intends to utilize commercial services in support of its lunar exploration program, including commercial launch services, and the Commercial Lunar Payload Services (CLPS) project for the delivery of science and technology payloads to the lunar surface. NASA is partnering with industry to develop Gateway and to support their activities on and near the Moon. The first element of the Gateway – the Power and Propulsion Element (PPE) – will be provided by Maxar Technologies as a public-private partnership with Maxar owning PPE through commercial launch and an on-orbit demonstration lasting up to one year. The Agency hopes to expand the commercial market into cislunar space and onto the lunar surface.

Additionally, NASA plans to support the development of the human lunar lander system that will return astronauts to the Moon in 2024 through a public-private partnership. This approach is modeled on and incorporates lessons learned from the successful Commercial Cargo and Commercial Crew programs.

NASA is also engaged in public-private partnerships with industry through the Next Space Technologies for Exploration Partnerships (NextSTEP) acquisitions for Habitation and Life support. Many of the component systems that are developed through these partnerships will result in solutions that have Earth-based applications for resilient structures, miniaturized monitoring technologies, CO_2 separation and reduction and indoor agriculture.

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

Answer 2. In the case of the Gateway, on May 24, 2019, Maxar Technologies was awarded a firm-fixed price contract to partner with NASA to develop and demonstrate the PPE element. The PPE BAA, released on September 6, 2018, provided a minimal set of NASA unique requirements allowing industry room to innovate and add their own objectives. Maxar will own and operate the PPE during development, launch, and flight demonstration. The flight demonstration will last as long as one year, after which NASA will have the option to acquire the residual post-demonstration in-flight asset for use as the first element of the Gateway.

The particular approaches to be employed in future acquisitions will depend on a variety of factors designed to match the unique circumstances of the procurement with the appropriate acquisition mechanism as well as applicable lessons learned from previous efforts.

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

Answer 3. While NASA defers to industry regarding their wider commercial business cases and terrestrial applications, it should be noted that the Gateway's PPE – provided by Maxar Technologies – demonstrates solar-electric propulsion capabilities that potentially have direct applicability to their current commercial satellites product lines, enabling more efficient station keeping as well as on-obit satellite delivery.

Question 4. How can the agency strike a balance between investing in U.S. companies that are developing innovative technologies and ensuring that we are maintaining the excellence of NASA's workforce and its homegrown technology?

Answer 4. Mission success is highly dependent on a skilled, technical workforce. NASA plans for workforce requirements annually based on Mission needs. NASA's workforce planning process has been designed to emphasize agility in all workforce segments (to include civil service, industry and academic partnerships, and on-and-near-site support contractors) and sharing of civil servants across Centers. In addition to annual workforce planning efforts, NASA convenes the Acquisition Strategy Council (ASC) to decide new mission work assignments. Such assignments can involve the use of existing in-house capabilities, procured industry capabilities, or partnership arrangements with international space agencies or other entities. ASC decisions related to internal work assignments are based on many factors, including workforce availability, expertise match, perceived competition with industry, as well as cost/schedule considerations.

Senate Committee on Commerce, Science, and Transportation

"Moon to Mars: NASA's Plan for Deep Space Exploration."

Senator Richard Blumenthal

Written Questions Submitted by Hon. Richard Blumenthal to Jim Bridenstine:

The Need For Diverse, Next-Generation Space Suits. Connecticut has been the leader in space suit development since the Apollo moon landing. Now, employers in my state are working with NASA to develop the next-generation space suit that could serve astronauts for decades to come.

The current design will be obsolete by 2024 – the suits are past their life expectancy and in need of technological updates. Connecticut employers (mostly UTC) make the current model and want to make the replacement, too. You mention in your written testimony that NASA's goal is to send to first women to the Moon. Yet, opportunities for women in space are hindered by the lack of availability of diverse space suit, i.e. ones that are manufactured in a variety of shapes and sizes, primarily to accommodate the smaller frames of female astronauts. There is no program in place yet for replacement and these space suits could be made in Connecticut. Companies in my state are ready and able to deliver on this technology.

Question 1: Has NASA decided if they will have new space suits and what is the plan for the future of the space suit program?

Answer 1: NASA is developing a flexible spacesuit architecture with common core subsystems that can be modified to support the needs of specific destinations from low-Earth orbit, to deep space, and to the lunar surface. NASA intends to demonstrate the core spacesuit technologies and subsystems applicable to both ISS-based operations and surface exploration through a series of subsystem demonstrations at ISS, culminating in delivery of a complete suit system in 2023 for an on-orbit demonstration at ISS prior to the 2024 mission.

NASA intends to complete remaining development, build, and certification of the first three flight units (one for demonstration at ISS, two for Artemis 3) in-house with individual components acquired from multiple vendors across the country. A separate production contract for future builds of the Government design will be competitively awarded before 2023 to ensure seamless transition into Artemis sustaining operations.

Question 2: Is NASA talking to industry about its plan?

Answer 2: Please see response to Question #1, above; NASA will be formulating an acquisition strategy in the months ahead. Industry has been integral to the development of the flexible spacesuit architecture and participated in numerous design meetings for the suit system as it has matured. NASA is talking with industry about their critical role initially as component providers and the longer-term need for an industry-led production operation.

Question 3: Does this plan include development of space suits specifically designed for women – given that 12 of the agency's 38 active astronauts are women?

Answer 3: The exploration pressure garment design has focused on improving fit and performance for the full range of astronaut sizes and is not uniquely driven by gender. The exploration pressure garment design and sizing scheme has been validated in over 30 test events with crew. The rear-entry adjustable upper torso design accommodates crew from the

1 percentile female shoulder breadth up to 99 percentile male, offering a significant improvement over all previous EVA suit systems and representing the smallest size ever built. There are various combinations of spacesuit elements that work together, and they are not uniquely driven by gender.

Question 4: Will you commit to ensuring that NASA's budget and plans provide for developing and retaining diverse, next-generation space suits and life support technologies, like those being developed in my state?

Answer 4: NASA's deep space exploration plans include expanding human presence into the solar system, including the Moon and Mars. These endeavors will require spacesuits and life support technologies.

Support For NASA Funding That Supports Connecticut's Aeronautics Industry. **Employers in my state are dependent on work with NASA on aeronautics, the science behind making aircraft fly more efficiently. Space travel may be the exciting part of the NASA portfolio, but aeronautics is by far the most important in terms of creating high quality jobs and exports, thus contributing significantly to our GDP.**

However, aeronautics investment represents only about 3 percent of NASA's budget and is decreasing every year. U.S. investment in aeronautics pales in comparison to other countries, including China.

Investment in aeronautics leads to new and innovative technologies – making us competitive in the global market.

Question 1: At what level should Congress annually fund aeronautics efforts at NASA?

Answer 1: NASA's funding requirement for aeronautics research is included in the President's Budget request, enabling NASA to accomplish our highest priority research activities.

Question 2: Given the importance of this technology-driven industry to our nation's economy, shouldn't we be increasing investment in aeronautics?

Answer 2: NASA agrees that it has an important role to research and develop technologies to support the continued global leadership of the U.S. aerospace industry. Future year budget requirements are included in the President's Budget request.

Senate Committee on Commerce, Science, and Transportation

"Moon to Mars: NASA's Plan for Deep Space Exploration."

Questions for the Record
Ranking Member Maria Cantwell

Written Questions Submitted by Hon. Maria Cantwell to Jim Bridenstine:

Question 1: The Space Station partners and others are eager to take part in a Moon exploration program. Why isn't NASA inviting international partners to join us in Moon 2024 landing in order to help with the cost?

Answer 1: NASA has and will continue to encourage additional international partnerships in the Artemis program. International partners are already participating in robotic precursor missions with the Science Mission Directorate and the Human Exploration and Operations Mission Directorate is working to enable the ISS partners' participation in the Artemis campaign. Our international partners are proceeding toward their respective stakeholders' approval and funding processes for provision of proposed elements, modules, and capabilities for the Gateway and other Artemis campaign systems. NASA weighs a number of factors in evaluating prospective international partner contributions to the Artemis campaign.

Question 2: We briefly discussed the importance of staying on cost and schedule for the Artemis program. You noted in your testimony that NASA does not have a great track record with cost estimates and executing programs on schedule. What will NASA do differently to ensure the new development activities, such as the lunar lander, being undertaken for Artemis are on time and on budget?

Answer 2: As we move forward to develop the Gateway, human landers, and other exploration systems in support of the Artemis missions, NASA is committed to developing more realistic cost and schedule estimates early on for our programs and performing independent assessments of these estimates with existing review authorities. This will make it easier for our Government and industry teams to execute to schedule.

Question 3: What are you doing to ensure that Artemis involves not only a female astronaut, but also engineers and scientists from underrepresented communities?

Answer 3: Building a strong and diverse science, technology, engineering and mathematics (STEM) workforce is essential to ensuring that the United States remains globally competitive in the 21st century and beyond. Therefore, the Nation must maintain its commitment to excellence in STEM to ensure that all Americans have a role in and responsibility for shaping our Nation's future. This is especially relevant in STEM fields where students and employees often work collaboratively to solve challenges. Thus, diverse teams think about problems in new and different ways and develop solutions that may not be identified or explored by teams with homogeneous backgrounds. Additionally, diverse teams drive greater innovation and creativity which results in a workforce that is more flexible and adaptable to changing work and new scientific developments. Ultimately, diversity is important in any workforce, not just amongst employees from STEM fields. NASA Offices, Mission Directorates, Centers and Facilities collaborate to implement a single Agency-wide approach to STEM engagement. This approach provides unique NASA experiences to students, educators, and institutions, as well as streamlined access to NASA content, websites, people, resources, and facilities.

As NASA prepares to land the first woman and the next man on the Moon by 2024, we envision having students across the nation join us in our journey. We envision NASA's direct work with students will attract and engage the Artemis generation – our future aerospace workforce – and stimulate interest in STEM careers across the Nation. NASA's unique contributions are vital to attracting the next-generation STEM workforce and will further NASA's strategic goals of exploration, science, aeronautics, and space technology. NASA is positioned to make valuable contributions in the Federal sector by providing mission-driven opportunities toward enhancing our Nation's STEM literacy, and by helping to build a vibrant and diverse next-generation STEM workforce. One example is Artemis Student Challenges, engaging students, including those from underrepresented communities, in activities designed to contribute to NASA's efforts to return humans to the Moon.

Building a strong STEM workforce for the 21st century and beyond requires the development of a strong and diverse pipeline for STEM, including women and individuals from other underrepresented and underserved groups. NASA develops and delivers activities that support the growth of the Agency's and the Nation's STEM workforce, help develop STEM educators, engage and establish partnerships with institutions, and inspire and educate the public.

Diverse Agency STEM engagement activities inspire, engage and educate girls and underrepresented minorities in STEM. Specifically, The INSPIRE Women Act (P.L. 115-7) directed NASA to encourage women and girls to study STEM and to pursue STEM careers. NASA's efforts in this area span across the scope of NASA's endeavors in public engagement and education, with a focus on mentorship and opportunities that provide all students, including young women and girls with experiences interacting with NASA's women in action. NASA endeavors to provide unique opportunities for K-12, undergraduate and graduate students to be exposed to STEM through a spectrum of engagement. Activities that reach the targeted demographic, while fulfilling a broader purpose, include:

- NASA astronaut appearances,
- Speakers Bureau, Girls & Boys mentoring opportunities,
- Aspire to Inspire website, and
- Summer Institute in Science, Technology, Engineering and Research

Going forward, NASA educational outreach activities will continue to leverage the Agency's unique mission of research and discovery as a powerful context for inspiration and student learning, sharing our inspirational activities with the broadest audience possible. To this end, NASA will continue to monitor its efforts to share the STEM message with diverse groups, including women and individuals from underrepresented and underserved groups, pledging to use these results as a stepping stone for more effective STEM outreach efforts. Additionally, NASA will continue to work toward attracting and retaining diverse employees in STEM career fields while also providing student access to NASA's world-class research and technology facilities, mission data and Agency technical experts.

Question 4: Please provide your plan for developing spacesuits for the Artemis mission.

Answer 4: NASA is developing a flexible spacesuit architecture with common core subsystems that can be modified to support the needs of specific destinations from low-Earth orbit to the lunar surface. NASA intends to demonstrate the core spacesuit technologies and subsystems applicable to both ISS-based operations and surface exploration through a series of subsystem demonstrations at ISS, culminating in delivery of a complete suit system in 2023 for an on-orbit demonstration at ISS prior to the 2024 mission.

NASA intends to complete remaining development, build, and certification of the first three flight units (one for demonstration at ISS, two for Artemis 3) in-house with individual components acquired from multiple vendors across the country. A separate production contract for future builds of the Government design will be competitively awarded before 2023 to ensure seamless transition into Artemis sustaining operations.

Question 5: Systems testing and safety are essential. How much input have the independent technical authorities at the agency had into the testing regime for components of the Artemis mission?

Answer 5: Independent technical authorities for safety, engineering, and health and medical provide independent views of Human Exploration and Operations Mission Directorate activities, ensure direction to the programs reflects the views of the NASA technical authority community, review and approve waivers to engineering, safety, and health and medical requirements, facilitate dissenting opinions, and facilitate the appeal process to ensure proper implementation and disposition to appropriate management levels, and keep the Agency Engineering, Safety, and Health and Medical leadership informed of program activities and issues. The technical authorities are responsible for ensuring that proper engineering and safety rigor, review, risk evaluation, resolution and coordination occur in critical technical issues at the Enterprise and Program Levels.

The Artemis Enterprise uses decision-making boards at various levels to establish and control the guidance, policy, programmatic, and technical baselines necessary to successfully implement the architecture. The Agency technical authorities are well represented in Artemis decision-making processes. They are members of the ESD Control Board (ECB) as well as the Joint Integration Control Board (JICB) and Joint Program Control Board (JPCB). The ECB is the decision-making entity for topics relating to the initiation, planning, formulation, implementation, and evaluation of ESD programs. The JPCB is a joint SLS, Orion, and EGS Program board that resolves issues among Programs where two or more Programs are involved. The JPCB serves as the decision-making forum to make policy and programmatic/technical decisions impacting more than one Program. The JICB dispositions integrated products assigned to the Programs and other cross-program technical issues.

In addition, Orion, Space Launch System (SLS), and Exploration Ground Systems (EGS) have program-level independent technical authorities who provide oversight and advice and serve on Program Control Boards that establish and control individual Program baselines, and serve as the decision-making forum within that Program for policy, programmatic and technical decisions. The independent technical authorities have been extensively involved in the development and review of the test and verification programs for SLS, Orion, and EGS, and the test plans have been reviewed at Preliminary Design Reviews and Critical Design Reviews.

Question 6: What is the justification for including on orbit delivery as a requirement for elements of Gateway and lander? How is the agency ensuring that all interested commercial companies are able to compete in a fair, balanced manner to participate in the Artemis program? Is NASA considering the risk that some of these launch vehicles will not be ready in time?

Answer 6: NASA intends for the Gateway and Human Landing System to involve contracts with commercial partners and that the Agency will support partners' activities on and near the Moon in furtherance of NASA's mission needs. The intent is for partners to provide an integrated, streamlined solution that reduces the number of handovers between industry and the Government and ensures partners have clear accountability for delivering functional hardware in support of NASA's lunar missions. That accountability includes providing commercial partners with the discretion and latitude to select dependable launch vehicles (which may include launch vehicle modifications) that meet their unique needs and help close their business cases in order to achieve mission success. Additionally, NASA's requirements necessitate proven launch vehicle capabilities and NASA retains appropriate levels of launch vehicle insight for each individual mission or mission component. NASA believes that the availability of commercial launch vehicles capable of supporting Artemis is of low risk.

NASA is pursuing full and open competition to the maximum extent practicable for the Artemis program. Allowing all interested commercial companies with capabilities to support the program the opportunities to participate is essential to bring down acquisition costs and bring new innovation to the program. To that end, NASA is strategically leveraging critical aspects of U.S. industry (including small businesses), as well as the support of international partners, in order to effectuate a sustainable human presence both in cislunar space and on the lunar surface.

Question 7: It is unclear at this point when commercial crew providers will be able to start flying astronauts to the International Space Station. What is NASA's plan to ensure continued access to the International Space Station in the event that commercial crew providers are not ready to start flying on the currently planned date?

Answer 7: NASA executed a modification to its contract with Roscosmos in March 2019 to obtain Soyuz transportation services for one U.S. crew member in late 2019 and one crew member in the spring of 2020 to ensure continued U.S. presence aboard the Space Station to maintain safe operations of the ISS and maximize the time dedicated to research on the orbiting laboratory until U.S. commercial crew providers begin sustained transportation operations.

In addition, NASA is in contract discussions with Roscosmos for services on a sole source basis for a potential Soyuz seat and associated services to the ISS. This transportation would be for one crewmember in the fall of 2020, with a return in the spring of 2021.

NASA is committed to launching U.S. astronauts aboard domestic spacecraft. Soyuz transportation provides flexibility and back-up capability without adding unnecessary schedule pressure to our U.S. commercial crew providers.

Senate Committee on Commerce, Science, and Transportation

"Moon to Mars: NASA's Plan for Deep Space Exploration."

Senator Amy Klobuchar

Written Questions Submitted by Hon. Amy Klobuchar to Jim Bridenstine:

Diversity in STEM. The National Association of Manufacturing recently reported that the U.S. will have to fill 3.5 million STEM jobs by 2025—with more than 2 million of them going unfilled because of the lack of highly skilled candidates. I introduced bipartisan legislation that passed this Committee earlier this month to encourage veterans and military spouses to pursue careers in STEM fields, and I also led bipartisan legislation to encourage women and minorities to pursue careers in aerospace and STEM that was signed into law in 2017.

Question 1: Do you agree that it is important to train a diverse workforce to fill STEM jobs, and if so, why?

Answer 1: Yes. Building a strong and diverse science, technology, engineering and mathematics (STEM) workforce is essential to ensuring that the United States remains globally competitive in the 21st century and beyond. Therefore, the Nation must maintain its commitment to excellence in STEM to ensure that all Americans have a role in and responsibility for shaping our Nation's future. This is especially relevant in STEM fields where students and employees often work collaboratively to solve challenges. Thus, diverse teams think about problems in new and different ways and develop solutions that may not be identified or explored by teams with homogeneous backgrounds. Additionally, diverse teams drive greater innovation and creativity which results in a workforce that is more flexible and adaptable to changing work and new scientific developments. Ultimately, diversity is important in any workforce, not just amongst employees from STEM fields. NASA Offices, Mission Directorates, Centers and Facilities collaborate to implement a single Agency-wide approach to STEM engagement. This approach provides unique NASA experiences to students, educators, and institutions, as well as streamlined access to NASA content, websites, people, resources, and facilities.

Building a strong STEM workforce for the 21st century and beyond requires the development of a strong and diverse pipeline for STEM, including women and individuals from other underrepresented and underserved groups. NASA develops and delivers activities that support the growth of the Agency's and the Nation's STEM workforce, help develop STEM educators, engage and establish partnerships with institutions, and inspire and educate the public.

Most of NASA's current data regarding its STEM Engagement efforts focuses on outputs of its educational activities (e.g., number of students and educators reached). NASA will continue to monitor its efforts to share the STEM message with diverse groups, including women and individuals from underrepresented and underserved groups, pledging to use these results as a stepping stone for more effective STEM outreach efforts. To this end, NASA is working on collecting better data on who accesses its programs. Through strategic use of NASA assets in its STEM Engagement offerings, NASA will continue to share its inspirational activities with a broader audience.

Question 2: What is NASA doing to encourage underrepresented groups and veterans to study STEM fields?

Answer 2: NASA has a long history of engaging students (which includes veterans and underrepresented communities) and the public in its missions. The Office of STEM Engagement has played a role in such engagement but does not constitute the whole effort, which is comprised of a broad and diverse set of programs, projects, activities and products developed and implemented by HQ functional Offices, Mission Directorates, and Centers. NASA as a whole has attracted, engaged, and educated students and the public, and will continue to do so.

Through Minority University Research and Education Project (MUREP), NASA provides financial assistance via competitive awards to Minority Serving Institutions (MSIs), including Historically Black Colleges and Universities, Hispanic Serving Institutions, Asian American and Native American Pacific Islander Serving Institutions, Tribal Colleges and Universities, and eligible community colleges. These institutions recruit and retain underrepresented and underserved students, including women and girls, and persons with disabilities, into STEM fields. MUREP investments assist faculty and students in research and provide authentic STEM engagement opportunities related to NASA missions.

Central to this strategy is a new architecture designed to enable relevant student contributions to NASA's mission and work, relying on mission drivers and requirements from NASA's Mission Directorates. NASA's work in STEM Engagement is focused on ultimately serving students as the beneficiary. In order to best serve students, the strategy includes three focus areas with associated objectives. They include:

Focus Area 1: Create unique opportunities for students to contribute to NASA's work in exploration and discovery.

- Obj. 1.1: Students contribute to NASA's endeavors in exploration and discovery.
- Obj. 1.2: Research and development capacity of educational institutions is enhanced, enabling broad and diverse contributions that directly address NASA priorities.

Focus Area 2: Build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content and facilities.

- Obj. 2.1: A broad and diverse set of students are attracted to STEM through NASA opportunities.
- Obj. 2.2: Students, including those from underrepresented and underserved communities, explore and pursue STEM pathways through authentic learning experiences and research opportunities with NASA's people and work.
- Obj. 2.3: The portfolio of NASA STEM engagement opportunities meets Agency workforce requirements and serves the nation's aerospace and relevant STEM needs.
- Obj. 2.4: Strategic partnerships with industry, academia, non-profit organizations and educational institutions enhance and extend the impact of NASA's efforts in STEM engagement.

Focus Area 3: Strengthen understanding by enabling powerful connections to NASA's mission and work.

- Obj. 3.1: Youth are introduced to STEM concepts and content through readily available NASA STEM engagement resources and content.
- Obj. 3.2: Students gain exposure to STEM careers through direct and virtual experiences with NASA's people and work.

NASA Offices, Mission Directorates, Centers and Facilities collaborate to implement a single Agency-wide approach to STEM education. This approach provides unique NASA experiences to students, educators, and institutions, as well as streamlined access to NASA content, websites, people, resources, and facilities. Internships and fellowships funded by the

Mission Directorates will continue to be supported and will continue to provide a mechanism for recruiting underrepresented students to STEM careers, including careers at NASA.

For more information on NASA STEM Engagement activities and opportunities, please visit www.nasa.gov/stem

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: MATERIAL FOR THE RECORD

HEARING ON

MOON TO MARS: NASA'S PLANS FOR DEEP SPACE EXPLORATION

JULY 17, 2019

From Senator Scott

Q: Are there things that we can do, that NASA can do, or Congress can help you do, that will create more incentives for States to invest or the private sector to make bigger investments and take more of the risk [of space development]?

A: Space Policy Directive-1 calls for NASA to "Lead 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 Agency's Next Space Technologies for Exploration Partnerships (NextSTEP) effort is a public-private partnership model that seeks commercial development of deep space exploration capabilities to support more extensive human spaceflight missions in and beyond cislunar space—the space near Earth that extends just beyond the Moon.

An important part of NASA's strategy is to stimulate the commercial space industry to help the Agency achieve its strategic goals and objectives for expanding the frontiers of knowledge, capability, and opportunities in space. A key component of the NextSTEP partnership model is that it provides an opportunity for NASA and industry to partner to develop capabilities that meet NASA human space exploration objectives while also supporting industry commercialization plans. For example, the NextSTEP Appendix H solicitation for the lunar Human Landing System (HLS) allows the private sector to take on more developmental risk by using a firm-fixed price, milestone-based proposal to enable rapid development and 2024 crewed flight demonstrations of HLS.

From Senator Markey

Q: NASA was appropriated $218 million for lunar science in Fiscal Year 2019. Mr. Administrator, has NASA been working with the National Academies and the broader academic community in determining the science projects that will be flown on the Commercial Lunar Payload Services?

A: Yes. NASA greatly values the expertise and advice of our colleagues at the National Academies and the broader academic community and works with them through various teams and committees. The Academies organize the production of community-written science overview documents that play a vital role in helping NASA prioritize what science should be undertaken. For the Moon, these include the 2013 Planetary Science Decadal "Voyages and Visions", as well as the 2007 "Scientific Context for the Exploration of the Moon" or SCEM report.

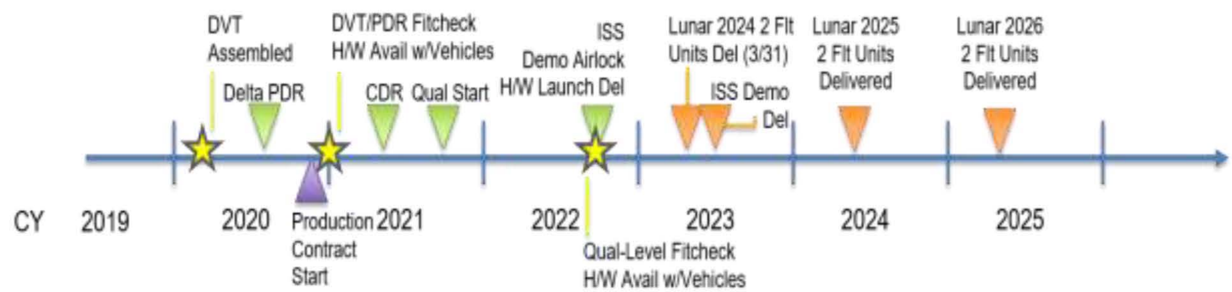
Broad-based community groups, such as the Lunar Exploration Analysis Group (LEAG), hold workshops and produce reports on a variety of lunar topics. The reports generated in these workshops, such as the 2017 LEAG Special Action Team Report Advancing Science of the Moon, the Lunar Science for Landed Missions workshop publication, in combination with the Planetary Science Decadal Survey, provide an open and balanced avenue for collaboration and advice from experts both at the National Academies and within the larger academic community.

Additionally, the instruments that have been selected to be delivered to the Moon using Commercial Lunar Payload Services (CLPS) landers were all competed using the NASA Provided Lunar Payloads (NPLP) internal call for ready or near-ready to fly instruments and the Lunar Surface Instruments and Technology Payloads (LSITP) broad community solicitation. The LSITP proposals that were received came from the science community and were peer reviewed. Future calls for instruments are planned at a regular cadence and will be openly competed.

From Senator Markey

Q: Please provide a timeline showing NASA's spacesuit development plan.

A: Consistent with direction in the P.L. 115-10, the NASA Transition Authorization Act of 2017, and leveraging prior investments by the ISS Program to advance technologies applicable to advanced space suits for use at multiple destinations, NASA's Advanced Exploration Systems Division is building a hi-fidelity Engineering Development Unit (EDU) of the Exploration Extravehicular Mobility Unit (xEMU), which will be completed in Fiscal Year 2020 (FY 2020). Following the completion of the EDU build and testing, NASA will perform the Critical Design Review (CDR) for the xEMU, followed by assembly and test of the qualification, ISS demonstration, and initial Lunar 2024 shipsets as shown below.



CDR – Critical Design Review
DVT – Design Verification Testing
PDR – Preliminary Design Review

It is anticipated that this xEVA Production and Services Contract could be phased-in as early as the CDR for xEMU in late FY 2020. With this approach, NASA would provide a snapshot of the most mature data set available with the Request for Proposal (RFP). At contract award, the contractor would be able to access the full CDR data as well as the "living" design documentation. This instrument would begin production deliveries in 2024 in order to support launch integration for future Artemis missions in 2025 and beyond.

Milestone Descriptions:

- Completed xEMU Core Systems Preliminary Design Review in July 2019
- Delivered initial EVA-to-HLS Interface Requirements Document to support the second draft release of Appendix H BAA in August 2019 and final Appendix H BAA in September 2019

- Conduct extensive ground Design Verification Test of complete xEMU in 2020
  - Lessons learned from the ground testing will be integrated into the final xEMU iteration for qualification testing

- Deliver thermal loop test article for launch to ISS at the end of 2019
  - Experiment will test the new suit water membrane evaporator (SWME, the heart of the space suit cooling system) along with two different pump technologies to get real in-flight data performance as we head into qualification hardware testing

- Demonstrate the xEMU outside ISS no later than FY2023
  - Includes demonstration of upgraded airlock interfaces
  - Early assessment of xEMU as potential upgrade for ISS operations

- Fly complete xEVA system on Artemis III in 2024

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION: QUESTIONS FOR THE RECORD

HEARING ON

MOON TO MARS: NASA'S PLANS FOR DEEP SPACE EXPLORATION

July 17, 2019

Written Questions Submitted to NASA Administrator Hon. James Bridenstine

Submitted by Senator Capito

Just last week, the Commerce Subcommittee on Aviation and Space heard from a distinct panel of witnesses, including West Virginia's very own Homer Hickam. The through-line over the course of the hearing was the United States must return to the Moon and have a human presence on earth's largest satellite. On March 26, 2019, Vice President announced the Artemis Program which will be NASA's path to the Moon and prepare ourselves for our next significant leap to Mars.

Question 1. **Administrator Bridenstine it is good to see you again, and thank you again for coming to West Virginia for the renaming of the Katherine Johnson Independent Verification and Validation (IV&V) Facility. What a tremendous way to honor a West Virginia pioneer. Additionally I am glad you made time to do a town hall with employees there and tour the WV Robotic Technology Center. Along those lines I wanted to give you the opportunity to share with the Committee what you announced in West Virginia regarding the work you want to do on Robotic Servicing. The partnership between the WVRTC and Maxar on the Dragonfly system, in conjunction with RESTORE-L, can play a critical role in our exploration program.**

- **Could you expand on that?**

A: NASA sees value in satellite servicing capabilities, and is leveraging investments from industry to spur development in commercial satellite servicing and in-space manufacturing capabilities. Maxar's SPace Infrastructure DExterous Robot (SPIDER-formerly known as Dragonfly) and Restore-L support mission needs in advancing in-space servicing capabilities that enable sustainable resource management in space. Maxar Technologies is providing both the Restore spacecraft bus and the SPIDER demonstration. In addition to the Restore project, the Goddard Space Flight Center Restore-L project is also managing SPIDER as a hosted payload on Restore-L. This project management approach will allow NASA to efficiently manage the programmatic aspects of both Dragonfly and Restore-L as an integrated project managed by the Goddard team. The Goddard Space Flight Center with the Restore-L contractor team, including Maxar Technologies, and its robotics partner, West Virginia University, will continue to play a critical role in developing the satellite servicing capabilities technologies that support Artemis (refueling, rendezvous and proximity operations, and cooperative servicing aids) as well as those of most interest to industry (specialized tools, dexterous robotics, fluid transfer, rendezvous and proximity operations, and cooperative servicing aids). With industry and academic partners, NASA will leverage Technology Transfer mechanisms and pursue partnerships with interested U.S. companies. This will provide a clear path to transferring the technologies to industry for multiple applications and lead to flight demonstrations based on industry business plans.

Question 2. **New private companies – like Blue Origin – have emerged to both compete and collaborate with NASA in order to move the space industry forward. Just this past April,**

Constellium – who has a manufacturing facility in Ravenswood, WV – announced a multi-year contract with Blue Origin to support their launch vehicle programs. This is a significant investment for communities like Ravenswood and has created an opportunity for this community to contribute to our space exploration and bolster our aerospace industrial base.

- **Could you discuss why it's important of having national programs and partnerships like the one in Ravenswood in order to sustain and grow our nation's space workforce?**

A: NASA is pursuing a lunar exploration campaign to establish U.S. preeminence to, around, and on the Moon through commercial and international partnerships. With the growth of technologies and innovations outside the Agency, NASA will utilize a partnership acquisition strategy, in part focusing on leveraging and collaborating with the private sector and academia to harness their innovations for our missions. NASA recognizes that American companies are on the cutting edge of space technology and are developing groundbreaking new technologies that will unleash new opportunities and economic growth. Drawing upon a highly diffuse and technical supply chain and workforce, firms at the leading edge of exploration represent a benchmark of national capability across a wide spectrum of activities.

Question 3. **It is clear that China has significant ambitions over the next 10 to 15 years to develop the capabilities in order to conduct manned lunar missions, that includes the development of super-heavy lift rockets, and set the stage for a new age in space exploration.**

- **Could you discuss the importance of the United States leading this new age in space exploration?**

A: China has ambitious human spaceflight plans, including a space station, the first component of which may launch in 2022. China's interest in the robotic and human exploration of the Moon only serves to underscore the importance of maintaining U.S. leadership in this important sphere of scientific and economic activity. We must decide now whether we build on our legacy of American preeminence and leadership in science, technology, and exploration, or yield that role to other nations which are investing significant resources in all of these areas, including, notably, space exploration.

- **Can you discuss the importance of the Space Launch System (SLS) and why we should have this capability?**

A: NASA's Space Launch System (SLS) is an advanced launch vehicle that provides the foundation for human exploration beyond low Earth orbit. With its unprecedented power and capabilities, SLS is the only rocket that can send Orion to the vicinity of the Moon on a single mission. It will offer more payload mass than any current launch vehicle.

Submitted by Senator Young

Question 1. **Administrator Bridenstine, given your testimony about the importance of leveraging outside partners and the creation of additional cooperative opportunities for the next steps in exploration beyond LEO, to what extent has NASA considered its statutory authority to employ previously used contractual vehicles such as University Affiliated Research Centers or Federally Funded Research and Development Centers, which enable NASA to tap into additional regions of the country and areas of expertise that can augment current NASA center workforce capabilities?**

A: NASA has considered and continues to evaluate these authorities.

The Agency is the sponsor of the Federally Funded Research and Development Center (FFRDC) known as the Jet Propulsion Laboratory (JPL) in Pasadena, CA. JPL is funded by NASA to meet specific long-term technical needs that cannot be met by any other single organization within NASA, and the lab is a unique national research facility that carries out robotic space and Earth science missions.

University Affiliated Research Centers (UARCs) provide specialized research and development services similar to FFRDCs and also operate under long-term contracts. The civil space work of the Johns Hopkins University Applied Physics Laboratory (APL) includes conducting research and space exploration; development and application of space science, engineering, and technology; and production of one-of-a-kind spacecraft, instruments, and subsystems.

Questions for the Record
Ranking Member Maria Cantwell

Written Questions Submitted by Hon. Maria Cantwell to Jim Bridenstine:

Question 1. The Space Station partners and others are eager to take part in a Moon exploration program. Why isn't NASA inviting international partners to join us in Moon 2024 landing in order to help with the cost?

Question 2. We briefly discussed the importance of staying on cost and schedule for the Artemis program. You noted in your testimony that NASA does not have a great track record with cost estimates and executing programs on schedule. What will NASA do differently to ensure the new development activities, such as the lunar lander, being undertaken for Artemis are on time and on budget?

Question 3. What are you doing to ensure that Artemis involves not only a female astronaut, but also engineers and scientists from underrepresented communities?

Question 4. Please provide your plan for developing spacesuits for the Artemis mission.

Question 5. Systems testing and safety are essential. How much input have the independent technical authorities at the agency had into the testing regime for components of the Artemis mission?

Question 6. What is the justification for including on orbit delivery as a requirement for elements of Gateway and lander? How is the agency ensuring that all interested commercial companies are able to compete in a fair, balanced manner to participate in the Artemis program? Is NASA considering the risk that some of these launch vehicles will not be ready in time?

Question 7. It is unclear at this point when commercial crew providers will be able to start flying astronauts to the International Space Station. What is NASA's plan to ensure continued access to the International Space Station in the event that commercial crew providers are not ready to start flying on the currently planned date?

Senator Amy Klobuchar

Written Questions Submitted by Hon. Amy Klobuchar to Jim Bridenstine:

<u>Diversity in STEM.</u> The National Association of Manufacturing recently reported that the U.S. will have to fill 3.5 million STEM jobs by 2025—with more than 2 million of them going unfilled because of the lack of highly skilled candidates. I introduced bipartisan legislation that passed this Committee earlier this month to encourage veterans and military spouses to pursue careers in STEM fields, and I also led bipartisan legislation to encourage women and minorities to pursue careers in aerospace and STEM that was signed into law in 2017.

Question 1. Do you agree that it is important to train a diverse workforce to fill STEM jobs, and

if so, why?

Question 2. What is NASA doing to encourage underrepresented groups and veterans to study STEM fields?

Senator Richard Blumenthal

Written Questions Submitted by Hon. Richard Blumenthal to Jim Bridenstine:

The Need For Diverse, Next-Generation Space Suits. Connecticut has been the leader in space suit development since the Apollo moon landing. Now, employers in my state are working with NASA to develop the next-generation space suit that could serve astronauts for decades to come. The current design will be obsolete by 2024 – the suits are past their life expectancy and in need of technological updates. Connecticut employers (mostly UTC) make the current model and want to make the replacement, too. You mention in your written testimony that NASA's goal is to send to first women to the Moon. Yet, opportunities for women in space are hindered by the lack of availability of diverse space suit, i.e. ones that are manufactured in a variety of shapes and sizes, primarily to accommodate the smaller frames of female astronauts. There is no program in place yet for replacement and these space suits could be made in Connecticut. Companies in my state are ready and able to deliver on this technology.

Question 1. Has NASA decided if they will have new space suits and what is the plan for the future of the space suit program?

Question 2. Is NASA talking to industry about its plan?

Question 3. Does this plan include development of space suits specifically designed for women – given that 12 of the agency's 38 active astronauts are women?

Question 4. Will you commit to ensuring that NASA's budget and plans provide for developing and retaining diverse, next-generation space suits and life support technologies, like those being developed in my state?

Support For NASA Funding That Supports Connecticut's Aeronautics Industry. Employers in my state are dependent on work with NASA on aeronautics, the science behind making aircraft fly more efficiently. Space travel may be the exciting part of the NASA portfolio, but aeronautics is by far the most important in terms of creating high quality jobs and exports, thus contributing significantly to our GDP.

However, aeronautics investment represents only about 3 percent of NASA's budget and is decreasing every year. U.S. investment in aeronautics pales in comparison to other countries, including China.

Investment in aeronautics leads to new and innovative technologies – making us competitive in the global market.

Question 1. At what level should Congress annually fund aeronautics efforts at NASA?

Question 2. Given the importance of this technology-driven industry to our nation's economy, shouldn't we be increasing investment in aeronautics?

Senator Edward J. Markey

Written Questions Submitted by Hon. Edward J. Markey to Jim Bridenstine:

Question 1. NASA has reportedly contracted with Idaho National Laboratory (INL) for a study evaluating the pros and cons of using highly enriched uranium (HEU) or low-enriched uranium in a space nuclear fission reactor. Please provide the following information on the study:

a. Who is leading this effort at INL and which other organizations, if any, are involved?
b. What specifically are the scope and parameters of the study?
c. When is it due and will you commit to providing Congress with a copy?

Question 2. Did Congress explicitly authorize funding for the development and recent testing of an HEU-fueled surface-power space nuclear reactor? Please provide details on the funding source within NASA's budget for this specific effort.

Question 3. A moderated reactor design in which the chain reaction is mediated by low-energy neutrons is more complicated to design than the Kilopower reactor, but it could be more compact than a fast-neutron LEU design. SNAP-10A, the only reactor that the US has launched into space, was a moderated system. Does NASA's research and development program for kilowatt-range surface-power systems also include an effort to design and test a moderated system, in addition to the recently tested fast-neutron Kilopower reactor?

Question 4. The Los Alamos and Idaho National Laboratories both specialize in fast-neutron reactors. Has NASA asked Oak Ridge National Laboratory or another organization that has more experience with slow-neutron reactors to compete for its space reactor project? Please describe in detail how NASA selected the entities involved in this study.

Senator Gary Peters

Written Questions Submitted by Hon. Gary Peters to Jim Bridenstine:

Question 1. I recently learned about an American Veteran Owned Small Business capable and eager to compete for NASA contracts to provide services currently being outsourced to foreign firms on a non-competitive basis. However, I am concerned about the use of international agreements that result in sole-source awards of large contracts to foreign owned companies. Does NASA have a policy to help ensure American companies can compete for service contracts against foreign sources? Will you commit to working with me to ensure American companies be allowed a fair opportunity to compete for taxpayer funded contracts rather than awarding sole-source contracts to foreign entities?

Question 2. The Department of Defense helped establish the Detroit-based Lightweight Innovations for Tomorrow (LIFT) institute. LIFT is a regional public-private partnership—with members from 25 states—that will contract on more than $100 million in R&D to develop and deploy lightweight manufacturing technologies. Lightweight materials are obviously critical for Moon and Mars operations. Separately, Congress has authorized NASA to create an advanced materials and manufacturing technology program for aeronautics. As an advocate of government efficiency, I'd hope NASA would take a look at existing opportunities such as LIFT to build on existing partnerships. Will you work with me to help ensure you are not reinventing the wheel here in establishing a new separate advanced materials program?

Question 3. I am proud that NASA recently announced Detroit-based Futuramic as its Supplier of the Year for working round-the-clock to help NASA speed up the production of the SLS rocket's massive core stage and meet NASA's new expedited timeline. I've visited their facilities [with Astronaut Charles Precourt] and seen the incredible work they're doing to help build the most powerful rocket in history. How do you see NASA leveraging the manufacturing capabilities of places like the Midwest to help us achieve this next great human milestone?

Question 4. You talked about the growing and important role of commercial companies in safely and promptly achieving NASA's goals, including Artemis. Unfortunately, the Commercial Space Federation has indicated that the FAA's new proposed licensing rules contain serious flaws that among other things could delay commercial launches needed for Artemis. Are you aware of their concerns and are you relaying those concerns to the Space Council and the Department of Transportation?

Question 5. In your testimony you mention *in situ* resource acquisition. China has announced plans for building a structure on the Moon using in situ resources. Can you share more about our plans for this and how far we are in developing our abilities for this?

Question 6. The only automobile to transport humans on another celestial body was first conceived by a University of Michigan professor *[and consultant to the U.S. Army Tank-Automotive Command's (TACOM's) Land Locomotion Laboratory at the Detroit Arsenal in Warren, Michigan]*. General Motors of course, later partnered with Boeing to build the Lunar Rover. Can you provide an update on NASA's plans for vehicles to transport astronauts on the Moon and Mars?

Senator Jackie Rosen

Written Questions Submitted by Hon. Jackie Rosen to Jim Bridenstine:

<u>Women in Space and STEM.</u> With the Artemis program, NASA will put the first woman on the Moon. Incredible women at NASA have paved the way for more women in space, but we still have a huge gap in representation. I have legislation – the Building Blocks of STEM Act – which would focus on giving our kids, and especially our girls, the opportunities to explore STEM-related fields from an early age. Research has shown it is critical to offer STEM opportunities and workforce development at an early age, especially to research historically underrepresented groups. Of those students who eventually work in the Aerospace and Defense workforce, 71% of

young professionals report they first became interested in these careers during their grade school years.

Question 1. What are other investments Congress should be considering to ensure that today's school-children are well equipped to lead our space exploration workforce?

Question 2. I know that NASA has many programs and initiatives aimed at breaking down barriers to girls and underrepresented minorities in STEM. Can you detail some of these?

Use of Commercial Technology. Much of the necessary technology and infrastructure needed to return to the Moon does not yet exist. For example, NASA plans to extract resources from the lunar surface. Engineers will need to figure out how to turn frozen water locked in the Moon's surface into drinkable water, breathable oxygen, and usable rocket fuel. In order to solve these problems, when possible, NASA can procure products or services from commercial companies to foster growth in the domestic space industry. NASA has long invested in the development of commercial services – in fact, since the beginning of the ISS commercial resupply and crew transportation programs, the United States' share of the global commercial launch market has gone from 0 percent in 2011 to 54 percent in 2017.

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

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

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

Question 4. How can the agency strike a balance between investing in U.S. companies that are developing innovative technologies and ensuring that we are maintaining the excellence of NASA's workforce and its homegrown technology?

Questions for the Record
Ranking Member Maria Cantwell

Written Questions Submitted by Hon. Maria Cantwell to Jim Bridenstine:

Question 1. The Space Station partners and others are eager to take part in a Moon exploration program. Why isn't NASA inviting international partners to join us in Moon 2024 landing in order to help with the cost?

Question 2. We briefly discussed the importance of staying on cost and schedule for the Artemis program. You noted in your testimony that NASA does not have a great track record with cost estimates and executing programs on schedule. What will NASA do differently to ensure the new development activities, such as the lunar lander, being undertaken for Artemis are on time and on budget?

Question 3. What are you doing to ensure that Artemis involves not only a female astronaut, but also engineers and scientists from underrepresented communities?

Question 4. Please provide your plan for developing spacesuits for the Artemis mission.

Question 5. Systems testing and safety are essential. How much input have the independent technical authorities at the agency had into the testing regime for components of the Artemis mission?

Question 6. What is the justification for including on orbit delivery as a requirement for elements of Gateway and lander? How is the agency ensuring that all interested commercial companies are able to compete in a fair, balanced manner to participate in the Artemis program? Is NASA considering the risk that some of these launch vehicles will not be ready in time?

Question 7. It is unclear at this point when commercial crew providers will be able to start flying astronauts to the International Space Station. What is NASA's plan to ensure continued access to the International Space Station in the event that commercial crew providers are not ready to start flying on the currently planned date?

Senator Amy Klobuchar

Written Questions Submitted by Hon. Amy Klobuchar to Jim Bridenstine:

<u>Diversity in STEM.</u> The National Association of Manufacturing recently reported that the U.S. will have to fill 3.5 million STEM jobs by 2025—with more than 2 million of them going unfilled because of the lack of highly skilled candidates. I introduced bipartisan legislation that passed this Committee earlier this month to encourage veterans and military spouses to pursue careers in STEM fields, and I also led bipartisan legislation to encourage women and minorities to pursue careers in aerospace and STEM that was signed into law in 2017.

Question 1. Do you agree that it is important to train a diverse workforce to fill STEM jobs, and

if so, why?

Question 2. What is NASA doing to encourage underrepresented groups and veterans to study STEM fields?

Senator Richard Blumenthal

Written Questions Submitted by Hon. Richard Blumenthal to Jim Bridenstine:

The Need For Diverse, Next-Generation Space Suits. Connecticut has been the leader in space suit development since the Apollo moon landing. Now, employers in my state are working with NASA to develop the next-generation space suit that could serve astronauts for decades to come. The current design will be obsolete by 2024 – the suits are past their life expectancy and in need of technological updates. Connecticut employers (mostly UTC) make the current model and want to make the replacement, too. You mention in your written testimony that NASA's goal is to send to first women to the Moon. Yet, opportunities for women in space are hindered by the lack of availability of diverse space suit, i.e. ones that are manufactured in a variety of shapes and sizes, primarily to accommodate the smaller frames of female astronauts. There is no program in place yet for replacement and these space suits could be made in Connecticut. Companies in my state are ready and able to deliver on this technology.

Question 1. Has NASA decided if they will have new space suits and what is the plan for the future of the space suit program?

Question 2. Is NASA talking to industry about its plan?

Question 3. Does this plan include development of space suits specifically designed for women – given that 12 of the agency's 38 active astronauts are women?

Question 4. Will you commit to ensuring that NASA's budget and plans provide for developing and retaining diverse, next-generation space suits and life support technologies, like those being developed in my state?

Support For NASA Funding That Supports Connecticut's Aeronautics Industry. Employers in my state are dependent on work with NASA on aeronautics, the science behind making aircraft fly more efficiently. Space travel may be the exciting part of the NASA portfolio, but aeronautics is by far the most important in terms of creating high quality jobs and exports, thus contributing significantly to our GDP.

However, aeronautics investment represents only about 3 percent of NASA's budget and is decreasing every year. U.S. investment in aeronautics pales in comparison to other countries, including China.

Investment in aeronautics leads to new and innovative technologies – making us competitive in the global market.

Question 1. At what level should Congress annually fund aeronautics efforts at NASA?

Question 2. Given the importance of this technology-driven industry to our nation's economy, shouldn't we be increasing investment in aeronautics?

Senator Edward J. Markey

Written Questions Submitted by Hon. Edward J. Markey to Jim Bridenstine:

Question 1. NASA has reportedly contracted with Idaho National Laboratory (INL) for a study evaluating the pros and cons of using highly enriched uranium (HEU) or low-enriched uranium in a space nuclear fission reactor. Please provide the following information on the study:

a. Who is leading this effort at INL and which other organizations, if any, are involved?
b. What specifically are the scope and parameters of the study?
c. When is it due and will you commit to providing Congress with a copy?

Question 2. Did Congress explicitly authorize funding for the development and recent testing of an HEU-fueled surface-power space nuclear reactor? Please provide details on the funding source within NASA's budget for this specific effort.

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National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

January 22, 2020

Reply to Attn of: OLIA/2019-00336:GA:dac

The Honorable Kendra Horn
Chairwoman
Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairwoman Horn:

Enclosed are responses to written questions submitted by you and Ranking Member Brian Babin resulting from the October 23, 2019, hearing entitled, ***"Space Weather: Advancing Research, Monitoring, and Forecasting Capabilities."*** Also enclosed are suggested edits to the hearing transcript.

This material completes the information requested during the hearing.

Sincerely,

Suzanne Gillen

Suzanne M. Gillen
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosures

cc: Chair Lizzie Fletcher

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Space Weather: Advancing Research, Monitoring, and Forecasting Capabilities"

Questions for the Record to:
Dr. Nicola Fox
Director
Heliophysics Division
National Aeronautics and Space Administration

Submitted by Subcommittee on Space and Aeronautics Ranking Member Brian Babin

1. How could NASA benefit from the space weather technological capabilities offered by the commercial sector?

    NASA could greatly benefit from the commercial sector by increased availability of rideshares or hosted payload opportunities. For example, the commercial sector could make available rideshare opportunities in which a research-grade space weather package with a real-time data stream could be flown on most commercial satellites. This would have a profound impact on NASA's ability to provide advanced understanding of space weather.

2. The main focus of the NASA Heliophysics program is fundamental research. How is NASA ensuring that its space weather research is being integrated into other agencies' operational space weather forecasting and mitigation? What could Congress do to help strengthen the connection between research and operations?

    NASA continues to work hand-in-hand with other federal agencies to transition its research to operational environments. Several Memoranda of Understanding (MOUs) between NASA, NOAA, and NSF do exactly this. They include identification of research models that would enable better space weather forecasts and then transitioning those to NOAA for operations. Additionally, NASA Heliophysics missions that have a real-time data stream are made available to NOAA. NASA instrument technology is transitioned for use on NOAA's space weather operational space observatories as needed. Currently, NASA and NOAA are developing a more formalized framework for transitioning research products to operations, the goal of which is make this process effective, efficient, sustainable, and flexible to accommodate of the agencies such as NSF, DoD, and USGS.

3. Small satellites, such as cubesats, are creating new opportunities for flexibility and low cost in a diverse range of space applications. Please describe how the NASA Heliophysics program is currently using small satellites for space weather research. What future opportunities seem most promising for additional use of small satellites? How can cubesats, rideshares, and hosted payloads stretch NASA's heliophysics budget?

NASA is leveraging the commercial sector CubeSat revolution to conduct research relevant to space weather. Most of NASA's CubeSat missions investigate phenomena that are directly related to space weather; for example, the natural disturbances of the ionosphere from the magnetosphere above and terrestrial atmosphere below. This is particularly relevant for space weather impacts on communication, navigation and the Global Positioning System (GPS). NASA is investigating the inclusion of small satellites and CubeSats in future strategic missions such as the Global Dynamic Constellation (GDC) mission, which also has relevance to the space weather impacts on communications and the power grid. Additionally, NASA Heliophysics has a dedicated CubeSat call for research.

4. Astronauts have not left the protection of Earth's magnetosphere since the end of the Apollo program in 1972. NASA's plans to return humans to the Mon, as soon as 2024, make space weather monitoring even more critical for astronaut safety. How do the research efforts of the heliophysics program interface with other NASA programs that are responsible for human space exploration and astronaut safety?
    a. To what extent would the accelerated timeline for returning astronauts to the lunar surface require changes in the research priorities for the heliophysics program? How would those changes affect the program's other research priorities?

    All NASA Heliophysics research programs are of great benefit to the space weather initiative and the Artemis program. Currently, we interact with astronaut safety programs, providing models and developing data products to help them forecast and determine all-clear conditions for astronaut extravehicular activities. Additionally, we are coordinating on the Artemis missions, including responding to the accelerated timeline for returning astronauts to the lunar surface. NASA is evaluating the possibility of launching an instrument package on the Gateway that would provide real-time radiation data products for astronaut safety and research opportunities. Furthermore, NASA is assessing the future needs associated with space weather impacts for human missions to Mars and how Heliophysics capabilities can be employed to enhance mission success. This includes space weather models and instruments to enable and enhance space weather forecasting. Human Mars missions will be Earth-independent, and thus will need on-board space weather observation and forecasting capability.

5. A 2008 National Academy report stated, "[s]pace weather, a global phenomenon that spans national boundaries, is a challenge best met by international cooperation." The report also described that the space weather landscape in Europe, our most likely international partner, was "complicated" and "very fragmented" and that "European data sources for space weather measurements are fairly limited." What percentage of the world's space weather monitoring and prediction is funded by the U.S.? Should the U.S. taxpayer subsidize other nation's space weather needs?

NASA Heliophysics is focused on research and does not conduct space weather monitoring or prediction. NASA does collaborate, when it is advantageous to the United States, with international space research agencies to conduct space-based investigations to better understand the coupled Sun-Earth system, and thus space weather. This is proven to be an effective means to get more science for the dollar. Additionally, there are international partners who have developed a few focused space weather models on specific aspects that are better than what we have in the U.S. Therefore, it is advantageous to continue these partnerships so long as they benefit NASA and the U.S. space weather enterprise.

6. Both the Obama Administration's "National Space Weather Strategy" and the Trump Administration's "National Space Weather Strategy and Action Plan" assigned space weather roles and responsibilities for numerous government agencies. Are specific agencies directed to be the primary agency for specific functions like research, standards development, operations, forecasting, notification, vulnerability assessment, critical infrastructure protection, or mitigation? What are the risks of having multiple different agencies contributing to every aspect of the nation's space weather enterprise? Should specific agencies be directed to lead certain space weather activities within the federal government?

    Recent advances in our understanding of space weather and the growing recognition across a broad spectrum of decision makers of the importance of this issue are in no small measure due to strong bipartisan support for the space weather enterprise. Addressing the impacts and mitigation of space weather for the Nation is naturally a multi-agency endeavor. The current "National Space Weather Strategy and Action Plan" identifies lead federal agencies and supporting agencies for the various components and activities of the plan. Agencies have complementary space weather responsibilities and each agency brings unique expertise and capability to the endeavor; we must collaborate to be successful. No one agency has the capability and capacity, let alone the resources, to successfully meet any of the top-level objectives of the National Space Weather Strategy and Action Plan.

7. Given your expertise, are there ground based systems that can improve predictability of space weather events or are there some in the research pipeline? What are they, where are they located and who funds them?

    There are several ground-based observatories and networks that provide critical research data products for space weather research; those include solar observatories, incoherent scatter radars[1], magnetometer and GPS receiver networks, and all-sky imagers. These important ground-based systems are located

[1] The incoherent scatter radar (ISR) technique is a powerful ground-based tool used to measure various properties of the ionized part of the upper atmosphere called the ionosphere. ISRs can be used to measure electron and ion temperatures and velocities, and the number densities of the electrons and the various ions.

across the US and the globe at locations appropriate for the type of observation that is made, e.g., high-altitude mountain tops for optical solar observatories, along particular longitudinal or latitudinal lines for magnetomer chains, and at certain latitudes for radars and all-sky imagers. NASA does not develop or sustain ground-based observatories, although in limited circumstances it has funded ground observations to validate or complement measurements from space missions. NSF and DoD fund several ground-based systems, while others are funded by international agencies.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Space Weather: Advancing Research, Monitoring, and Forecasting Capabilities"

Questions for the Record to:
Dr. Nicola Fox
Director
Heliophysics Division
National Aeronautics and Space Administration

Submitted by Subcommittee on Space and Aeronautics Chairwoman Kendra Horn

1. Many of our Heliophysics spacecraft are beyond, sometimes well beyond, their original prime mission lifetimes. How important are missions like the Solar and Heliophysics Observatory (SOHO, launched in 1995), the Solar Terrestrial Relations Observatory (STEREO, launched in 2006), and others currently operating in extended phase to our space weather capabilities?
    a. What gaps will exist when these missions end, and what would be the scientific impact of those gaps?
    b. To what extent, if any, does NASA consider operational requirements and interests in the planning, design, and development of its Heliophysics missions, in relation to the research and scientific requirements and interests?

    Most of the 19 Heliophysics missions in operation are in extended operations. These missions each are successful in achieving their research goals, and all of them provide data and scientific understanding which are crucial to the space weather initiative, and therefore, are all directly related to space weather. Many of our strategic missions were designed to have the capability to produce real time or tailored products that support the user community in real time, such as STEREO and SDO. They were intentionally developed to support space weather research in addition to their prime science objectives. With the recent establishment of the Heliophysics Space Weather Science Application program, NASA is in the process of assessing and developing a strategy to address the gaps that will inevitably occur. Included in this strategy will be to continue to leverage existing missions in development when appropriate, to accommodate space weather capability, such as real-time beacons or a small space weather package, to secure a focused space weather science mission, to seek share ride opportunities with space weather observations, and to explore concepts of dispersed constellation missions using CubeSats and small satellites.

2. Your prepared testimony highlights NASA's current efforts to work with NOAA to "develop a shared framework for research to operations." What will the shared framework involve?
    a. How are the Space Weather Prediction Center's operational challenges informing the space weather research priorities at NASA?
    b. Are we doing as well as we could be to ensure that there is a robust operations-to-research activity?

c. What types of assessments or reviews does NASA or other partners conduct of the research-to-operations and operations-to-research processes?

The shared framework with NOAA is still in development. It will involve NASA and NSF on the research side and NOAA, DoD, USGS, and others on the operations side. The shared framework will significantly engage the commercial sector and academic community as it is through these communities that the majority of the research and technology innovation is produced. Initially, framework development is focused on establishing the process between NASA and NOAA, as these agencies are the primary funders of space weather research and operations. Once this is accomplished we plan to expand the effort to include other agencies. We see this shared framework as a means to ensure a robust research-to-operations-to research activity. By instilling a process with discipline yet flexibility to accommodate particular aspects of each transition and with validation/verification of the model or technology being transitioned, the expectation is that this will be a significant improvement over previous efforts. Independent assessments of the process will be conducted regularly, especially as agency participation increases. The expectation is that each agency, commercial sector, and academic community will have particular approaches and needs that will require flexibility to be built in the framework.

3. In response to my question on gaps in our space weather forecasting capabilities, Mr. Murtaugh noted that "there are so many unfortunately," that he limited his comments to the Sun, and that he "could share all the way down to Earth with some of the serious challenges we face." Is there a full identification of the gaps in our space weather forecasting capabilities beyond the ones you and Mr. Murtaugh highlighted in response to my question? If so, please provide it for the record. If not, what process do you recommend for identifying the complete set of gaps?

There are known gaps in our understanding of space weather. The current National Space Weather Strategy and Action Plan calls for a bi-annual review by NASA and NSF of the state of space weather research and identification of the top research challenges. An incomplete list of known gaps in understanding includes:

- what drives the active regions on the Sun and how we can predict when one will explode;
- what accelerates the solar wind from the surface of the Sun to the Earth, how we can better predict when it will arrive at Earth, and what its characteristics will be, such as velocity, composition, density, and magnetic field strength and direction;
- what causes some solar storms to have a significant impact at Earth when other, apparently similar, events do not and how we can predict the magnitude of the impact;
- what drives and regulates Earth's radiation belts and how we can predict their state or configuration; and,
- what causes the ionospheric variability that disrupts communication and GPS scintillation and can we predict when it will occur and how intense it will be.

Suggested NASA edits for House Science space weather hearing transcript on 10/23/19

Throughout: Should be Dr. Fox, not Ms. Fox
Line 484-485: delete "—at"
Line 969: delete "The—"
Line 1160: should read "...I've seen that before..."
Line 1506: delete "the—"
Line 1617: delete "that—"
Line 1635: should read, "And then I'll just throw in – I know..."

EDDIE BERNICE JOHNSON, Texas
CHAIRWOMAN

FRANK D. LUCAS, Oklahoma
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6375
www.science.house.gov

November 19, 2019

Dr. Nicola Fox
Director
Heliophysics Division
National Aeronautics and Space Administration
300 E Street SW
Washington, D.C. 20546

Dear Dr. Fox,

On behalf of the Subcommittee on Environment and Subcommittee on Space and Aeronautics of the House Committee on Science, Space, and Technology, we want to express our sincere appreciation for your participation in the hearing ***"Space Weather: Advancing Research, Monitoring, and Forecasting Capabilities"*** on Wednesday, October 23, 2019.

We have attached a transcript of the hearing for your review. The Committee's rule pertaining to the printing of transcripts is as follows:

> *The transcripts of those hearings conducted by the Committee, when it is decided they will be printed, shall be published in substantially verbatim form, with the material requested for the record inserted at that place requested, or at the end of the record, as appropriate. Individuals, including Members, whose comments are to be published as part of a Committee document shall be given the opportunity to verify the accuracy of the transcription in advance of publication. Any requests by those Members, staff, or witnesses to correct any errors other than errors in the transcript, or disputed errors in transcription, shall be appended to the record, and the appropriate place where the change is requested will be footnoted. Prior to approval by the Chair of hearings conducted jointly with another Congressional Committee, a memorandum of understanding shall be prepared which incorporates an agreement for the publication of the transcript.*

Transcript edits, if any, should be submitted by **Tuesday, December 3rd, 2019**. If no edits are received by the above date, we will presume that you have no suggested edits to the transcript.

We are also attaching questions submitted for the record by Members of the Committee. Please submit answers to all of the enclosed questions no later than **Tuesday, December 3rd, 2019.**

All transcript edits and responses to questions should be submitted to us and directed to the attention of Aria Kovalovich, Research Assistant at the Subcommittee on Environment. If you have any further questions or concerns, please contact Aria at (202) 225-0465.

Sincerely,

Lizzie Fletcher

Representative Lizzie Fletcher
Chair
Subcommittee on Environment
Committee on Science, Space, and Technology

Kendra S Horn

Representative Kendra Horn
Chairwoman
Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology

Enclosure: Questions for the Record
Attachment: Transcript

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Space Weather: Advancing Research, Monitoring, and Forecasting Capabilities"

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Dr. Nicola Fox
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Submitted by Subcommittee on Space and Aeronautics Ranking Member Brian Babin

1. How could NASA benefit from the space weather technological capabilities offered by the commercial sector?

2. The main focus of the NASA Heliophysics program is fundamental research. How is NASA ensuring that its space weather research is being integrated into other agencies' operational space weather forecasting and mitigation? What could Congress do to help strengthen the connection between research and operations?

3. Small satellites, such as cubesats, are creating new opportunities for flexibility and low cost in a diverse range of space applications. Please describe how the NASA Heliophysics program is currently using small satellites for space weather research. What future opportunities seem most promising for additional use of small satellites? How can cubesats, rideshares, and hosted payloads stretch NASA's heliophysics budget?

4. Astronauts have not left the protection of Earth's magnetosphere since the end of the Apollo program in 1972. NASA's plans to return humans to the Mon, as soon as 2024, make space weather monitoring even more critical for astronaut safety. How do the research efforts of the heliophysics program interface with other NASA programs that are responsible for human space exploration and astronaut safety?
    a. To what extent would the accelerated timeline for returning astronauts to the lunar surface require changes in the research priorities for the heliophysics program? How would those changes affect the program's other research priorities?

5. A 2008 National Academy report stated, "[s]pace weather, a global phenomenon that spans national boundaries, is a challenge best met by international cooperation." The report also described that the space weather landscape in Europe, our most likely international partner, was "complicated" and "very fragmented" and that "European data sources for space weather measurements are fairly limited." What percentage of the world's space weather monitoring and prediction is funded by the U.S.? Should the U.S. taxpayer subsidize other nation's space weather needs?

6. Both the Obama Administration's "National Space Weather Strategy" and the Trump Administration's "National Space Weather Strategy and Action Plan" assigned space

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Space Weather: Advancing Research, Monitoring, and Forecasting Capabilities"

Questions for the Record to:
Dr. Nicola Fox
Director
Heliophysics Division
National Aeronautics and Space Administration

Submitted by Subcommittee on Space and Aeronautics Chairwoman Kendra Horn

1. Many of our Heliophysics spacecraft are beyond, sometimes well beyond, their original prime mission lifetimes. How important are missions like the Solar and Heliophysics Observatory (SOHO, launched in 1995), the Solar Terrestrial Relations Observatory (STEREO, launched in 2006), and others currently operating in extended phase to our space weather capabilities?
    a. What gaps will exist when these missions end, and what would be the scientific impact of those gaps?
    b. To what extent, if any, does NASA consider operational requirements and interests in the planning, design, and development of its Heliophysics missions, in relation to the research and scientific requirements and interests?

2. Your prepared testimony highlights NASA's current efforts to work with NOAA to "develop a shared framework for research to operations." What will the shared framework involve?
    a. How are the Space Weather Prediction Center's operational challenges informing the space weather research priorities at NASA?
    b. Are we doing as well as we could be to ensure that there is a robust operations-to-research activity?
    c. What types of assessments or reviews does NASA or other partners conduct of the research-to-operations and operations-to-research processes?

3. In response to my question on gaps in our space weather forecasting capabilities, Mr. Murtaugh noted that "there are so many unfortunately," that he limited his comments to the Sun, and that he "could share all the way down to Earth with some of the serious challenges we face." Is there a full identification of the gaps in our space weather forecasting capabilities beyond the ones you and Mr. Murtaugh highlighted in response to my question? If so, please provide it for the record. If not, what process do you recommend for identifying the complete set of gaps?

weather roles and responsibilities for numerous government agencies. Are specific agencies directed to be the primary agency for specific functions like research, standards development, operations, forecasting, notification, vulnerability assessment, critical infrastructure protection, or mitigation? What are the risks of having multiple different agencies contributing to every aspect of the nation's space weather enterprise? Should specific agencies be directed to lead certain space weather activities within the federal government?

7. Given your expertise, are there ground based systems that can improve predictability of space weather events or are there some in the research pipeline? What are they, where are they located and who funds them?

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

March 13, 2020

Reply to Attn of: OLIA/2018-00001:JG:dac

The Honorable Gerald Connolly
Chairman
Subcommittee on Government Operations
Committee on Oversight and Reform
U.S. House of Representatives
Washington, DC 20515

Dear Chairman:

Enclosed is material requested for the record and responses to written questions submitted by Chairman Connolly resulting from the December 11, 2019 hearing, "*FITARA 9.0.*"

This material completes the information requested during that hearing.

Sincerely,

Suzanne M. Gillen

Suzanne M. Gillen
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosures

cc: The Honorable Mark Meadows, Ranking Member

Questions for Ms. Renee P. Wynn
Chief Information Officer, National Aeronautics and Space Administration
Questions from Chairman Gerald E. Connolly
December 11, 2019, Hearing: "FITARA 9.0"

1. How does data center consolidation and optimization fit into the cloud migration plans for the National Aeronautics and Space Administration?

NASA Response: Since 2010, NASA has closed 60 data centers and through the end of FY 2019 generated $32.36M in data center savings and cost avoidance. This is a 75 percent reduction, resulting in the repurposing of approximately 80,000 square feet of space and generating about $36.2 million in savings since FY 2012. When reducing our data center footprint, we also increased our use of cloud computing. NASA currently has more than 10 petabytes of data in the cloud and uses more than 1.4 million commercial cloud-computing hours per month. While cloud usage is more expensive upfront, ultimately, it is a smarter way of doing business. Newer programs like Artemis are even designing their missions with the cloud in mind from the beginning. However, this is just a start. As NASA becomes more established in the cloud, NASA will return our focus to data center consolidation, seeking additional efficiencies there.

Cloud computing offers some strategic advantages to NASA. The use of cloud computing (and moving the data outside the boundaries of NASA's internal networks) enables NASA's extensive portfolio of public science data to be easily accessible to the global science community and enables greater collaboration with NASA's external partners of all kinds. As computational challenges become larger and more complex and an increasing number of scientists need to analyze larger and larger data sets, leveraging the dynamic scalability of cloud computing to utilize (rent) large quantities of processors on demand that NASA could never afford to own allows NASA to solve much larger computing problems and derive more discoveries from science data sets.

Laying the groundwork for broad cloud adoption, NASA implemented an enterprise cloud framework in order to minimize start-up time and costs. Key infrastructure services including networking, authentication and security compliance are pre-integrated into this environment to allow cloud users to get started quickly. The cloud framework cuts months from the cloud learning curve, significantly reduces "pioneering" costs and reduces duplication of effort.

Determining what applications to migrate to the cloud requires evaluation of a number of business considerations. The migration of legacy applications to the cloud is only marginally efficient if done as a "lift and shift" without redeveloping the application to leverage the benefits of cloud. Redeveloping legacy applications in the cloud is a significant software development project. Consideration should be given to the lifecycle stage of the application, the long-term need for the application and whether that capability is (or might become) available for delivery as Software as a Service. Most modern commercial applications will be available (perhaps exclusively) through cloud-based Software as a Service within the next five years.

NASA is moving toward a state where most new projects, applications and missions will be born in the cloud. In order to support future high data rate missions, science data processing and delivery systems are being redeveloped as cloud native to provide better accessibility of public data and faster delivery to waiting science teams, as well as limiting investments in additional data center computing hardware.

Over the next five to 10 years, NASA's growth in applications will primarily happen in the cloud. Legacy applications that reach end of life will be eliminated from data centers. Legacy applications that migrate to cloud will further reduce data center inventories. There will likely be a point in time when it will be prudent to revisit the data center utilization vs. data center footprint and consider another round of data center compressions/consolidation.

2. NASA scored its worst grade, an "F," on the risk transparency metric. According to the Government Accountability Office's review, NASA was the only agency to not rate any of its IT investments as a moderate or high risk. Why does NASA not identify any risk associated with more than $400 million in IT spending? Is NASA considering a change to its risk calculation policies?

__NASA Response:__ NASA does identify and assess risks for information technology (IT) investments including the risks associated with the Major IT Investments that make up the $400 million in IT spending. NASA's major IT Investments used in the risk transparency scoring are in the operations and maintenance lifecycle phase. The NASA Chief Information Officer's (CIO) assessments showed that these investments are vital to NASA's mission, are closely monitored and have effective plans in place, resulting in a "green" risk rating. The rating areas assessed include performance, human capital, risk management, contract/acquisition management, requirements management, incremental development, dependency risks and system risk management. In FY 2020, NASA is updating the assessment to incorporate additional cybersecurity metrics into the CIO risk rating process. Additionally, NASA will include Standard IT Investments, currently assessed monthly, to the Major IT Investment in the risk rating reporting.

3. What is the best policy or practice that NASA has implemented to achieve the requirements of the Federal IT Acquisition Reform Act (FITARA)? What improvements to the agency's IT posture did that policy or practice achieve?

__NASA Response:__ When enacted, FITARA facilitated NASA evolution from a highly decentralized to an enterprise IT environment. One area of attention was improving what was included in the overall NASA IT portfolio. Working with our stakeholders, NASA implemented an IT portfolio structure that provides transparency and visibility into NASA's IT spend. Once this was completed, NASA aligned our IT investments with the Technology Business Management taxonomy. Implementing the Technology Business Management taxonomy has provided additional insights into the IT spend for NASA. The IT governance changes implemented by NASA ensured the CIO's participation in Agency IT investment decisions for Agency missions as well as clarified the CIO's IT decision-making authority as chair of the IT Council (ITC) and a member of Agency-level management councils.

Material for the Record Response to Ranking Member Meadows

Ranking Member Meadows asked NASA and DHS to develop list of three things they would each focus on in CY 2020 to improve their next FITARA scores. For NASA, the Congressman said one area should be Data Center consolidation.

NASA Response:

- **Data Center Consolidation & Smart Cloud Expansion** – Since 2010, NASA has closed 60 data centers and through the end of FY 2019 generated $32.4 million in data center savings and cost avoidance. This is a 75 percent reduction, resulting in the repurposing of approximately 80,000 square feet of space and generating about $36.2 million in savings since FY 2012. When reducing our data center footprint, we also increased our use of cloud computing. NASA currently has more than 10 petabytes of data in the cloud and uses more than 1.4 million commercial cloud computing hours per month. While cloud usage is more expensive upfront, ultimately, it is a smarter way of doing business. Newer programs like Artemis are even designing their missions for the cloud. As NASA becomes more established in the cloud, NASA will return our focus to data center usage, seeking additional efficiencies there. Cloud computing offers some strategic advantages to NASA, as it enables NASA's extensive portfolio of public science data to be easily accessible to the global science community and enables greater collaboration with NASA's external partners.

- **Cybersecurity** – Protecting and modernizing NASA's IT infrastructure is and will remain a top Agency priority. NASA will continue our progress to mature our cybersecurity program. This includes, but is not limited to:
    - Supply Chain Risk Management (SCRM): We continue to work diligently to address the findings from the May 2018 NASA Inspector General (OIG) audit related to NASA's IT supply chain risk management efforts and are scheduled to correct the two remaining findings by the end of FY 2020.
    - Cybersecurity Workforce: Working with NASA's Office of the Chief Human Capital Officer to capitalize on the new hiring authority and other hiring practices that may be applicable to the Federal cyber workforce.

CAROLYN B. MALONEY
CHAIRWOMAN

ONE HUNDRED SIXTEENTH CONGRESS

JIM JORDAN, OHIO
RANKING MINORITY MEMBER

Congress of the United States

House of Representatives

COMMITTEE ON OVERSIGHT AND REFORM
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January 6, 2019

Ms. Renee P. Wynn
Chief Information Officer
National Aeronautics and Space Administration
300 E. Street, S.W.
Washington, D.C. 20546

Dear Ms. Wynn:

Enclosed are questions that have been directed to you and submitted for the official record for the hearing on Wednesday, December 11, 2019, titled "FITARA 9.0."

Please return your written responses to these questions by Wednesday, January 22, including each question in full as well as the name of the Member. Your response should be addressed to the Committee office at 2157 Rayburn House Office Building, Washington, D.C. 20515. Please also send an electronic version of your response by email to Amy Stratton, Clerk, at Amy.Stratton@mail.house.gov.

Thank you for your prompt attention to this request. If you need additional information or have other questions, please contact Elisa LaNier, Chief Clerk, at (202) 225-5051.

Sincerely,

Gerald E. Connolly
Chairman
Subcommittee on Government Operations

Enclosure

cc: The Honorable Mark Meadows, Ranking Member

Questions for Ms. Renee P. Wynn
Chief Information Officer, National Aeronautics and Space Administration

Questions from Chairman Gerald E. Connolly

December 11, 2019, Hearing: "FITARA 9.0"

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