A REVIEW OF THE PRESIDENT'S FISCAL YEAR 2022 BUDGET PROPOSAL FOR NASA

HEARING

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

OF THE

HOUSE OF REPRESENTATIVES

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June 23, 2021

A REVIEW OF THE PRESIDENT'S FISCAL YEAR 2022 BUDGET PROPOSAL FOR NASA

WEDNESDAY, JUNE 23, 2021

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

The Committee met, pursuant to notice, at 10:02 a.m., in room 2318 of the Rayburn House Office Building and via Webex, Hon. Eddie Bernice Johnson [Chairwoman of the Committee] presiding.

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

HEARING CHARTER

A Review of the President's Fiscal Year 2022 Budget Proposal for NASA

Wednesday, June 23, 2021
10:00 a.m.
Rayburn 2318/Zoom

PURPOSE

The purpose of the hearing is to review the Administration's Fiscal Year (FY) 2022 budget request for the National Aeronautics and Space Administration (NASA), and related issues.

WITNESSES

- **The Honorable Bill Nelson,** Administrator, National Aeronautics and Space Administration

OVERARCHING QUESTIONS

- *What new initiatives or terminations are proposed in the FY2022 budget request for NASA, and why?*
- *What is the relative balance, as proposed in the FY2022, budget request among human exploration, science, space technology, and aeronautics?*
- *What is the plan, including goals and objectives, for NASA's Moon to Mars campaign, and to what extent does the FY2022 budget proposal support implementation of the plan?*
- *What is the Administration's current understanding of the near- and long-term impacts of the COVID-19 pandemic on NASA's research and development projects and operations?*

BACKGROUND

The Administration has requested $24.8 billion for NASA in its Fiscal Year (FY) 2022 budget request, an increase of approximately $1.5 billion, or 6.6 over the FY2021 enacted appropriation.

As stated in the Congressional Justification document, the Administration's priorities for NASA's FY2022 proposal are: addressing climate change; a Moon to Mars human and robotic exploration plan; maintain and advance U.S. leadership in aviation and space; development of cutting-edge technologies and space science; and investing in science, technology, engineering and mathematics (STEM) engagement. Key initiatives proposed to support these priorities include the Earth System Observatory, the Sustainable Flight National Partnership, and keeping NASA on the path to landing the first woman and first person of color on the Moon under the Artemis program.

The FY2022 request notes that the long-term impacts of the COVID-19 pandemic on the agency's programs and activities are difficult to project and a full accounting of those impacts will not be available until after NASA has returned to normal operations. While NASA has taken steps to mitigate some of COVID-19 impacts through the use of cost reserves and schedule margins, "there is increased overall risk to the Agency's cost and schedule commitments for the foreseeable future."[1]

BUDGET ACCOUNTS

The programs in the Administration's FY2022 NASA budget proposal are summarized below by major organization (directorate or office). All budget numbers provided here are based on the information in the NASA FY2022 Congressional Budget Justification document[2] and the legislative text and explanatory statement of the Consolidated Appropriations Act, 2021.[3]

Human Exploration and Operations Mission Directorate

The Human Exploration and Operations Mission Directorate (HEOMD) manages the agency's activities related to human space exploration in and beyond low Earth orbit (LEO) in two accounts: Deep Space Exploration Systems and Space Operations. In FY2022, the administration is requesting $10.9 billion for HEOMD overall, an increase of $392.2 million (3.7%) from the FY2021 appropriation.

Table 1: NASA HEOMD Budget ($ millions)

	FY21 Enacted	FY22 Request	Change FY22 - FY21	
			Amount	Percent
NASA Total	**23,271.28**	**24,801.5**	**1,530.22**	**6.6%**
Human Exploration and Operations Mission Directorate	**10,505.6**	**10,897.8**	**392.2**	**3.7%**
Deep Space Exploration Systems	6,517.4	6,880.4	363.0	5.6%
Exploration Systems Development	4,544.6	4,483.7	-60.9	-1.3%
Exploration Research and Development	1,972.8	2,396.7	423.9	21.5%
Space Operations	3,988.2	4,017.4	29.2	0.7%
International Space Station	1,321.6	1,327.6	6.0	0.5%
Space Transportation	1,872.9	1,771.7	-101.2	-5.4%
Space and Flight Support	776.6	817.0	40.4	5.2%
Commercial LEO Development	17.0	101.1	84.1	494.7%

Source: NASA, FY2022 Budget Request Congressional Justification

[1] In its March 2021 memorandum on "COVID-19 Impacts on NASA Major Programs and Projects," the NASA Inspector General estimated that the total COVID impact to NASA would be approximately $3 billion. As part of the CARES Act (P.L. 116-36), Congress appropriated $60 million to NASA for mission delays and contractor costs (including back pay), enhanced information technology infrastructure, facility cleaning, and personal protective equipment. Available at: https://oig.nasa.gov/docs/IG-21-016.pdf.

[2] Available at: https://www.nasa.gov/sites/default/files/atoms/files/fy2022_congressional_justification_nasa_budget_request.pdf.

[3] P.L. 116-260. Available at: https://www.congress.gov/bill/116th-congress/house-bill/133.

Deep Space Exploration Systems

The Administration's FY2022 request proposes $6.88 billion for Deep Space Exploration Systems, a $363 million (5.6%) increase over the FY2021 enacted level. The entire Deep Space Exploration Systems account supports the Artemis Moon to Mars campaign with research and development of systems and capabilities for human exploration of deep space, defined as beyond LEO.

Exploration Systems Development (ESD). The FY2022 request for Exploration Systems Development is $4.48 billion, a decrease of $60.9 million (1.3%) from the FY2021 appropriation. Within ESD, the Administration is proposing: $1.4 billion for the Orion crew vehicle program ($3 million, or 0.2%, below the FY2021 enacted level); $2.5 billion for the Space Launch System (SLS) launch vehicle program ($74 million, or 3%, below the FY2021 enacted level); and $590 million for the Exploration Ground Systems (EGS) program ($10 million, or 1.7%, below the FY2021 enacted level).

The ESD systems—SLS, Orion, and EGS—will enable crew transportation for the Artemis missions to destinations in cislunar space and lunar orbit. The current launch readiness date (LRD) for Artemis I, the first uncrewed flight of the integrated SLS, Orion, and EGS systems, is no earlier than November 2021. The current launch readiness date (LRD) for Artemis II, the first crewed flight of the integrated SLS, Orion, and EGS systems, is no earlier than September 2023. According to the FY2022 budget request, NASA will update the Artemis I and II launch dates after the completion of a cost and schedule review, currently underway. The request proposes funding for development of the SLS Exploration Upper Stage and a second Mobile Launch Platform, both of which would enable a higher lift capability to low-Earth orbit and cislunar space in the SLS Block 1B configuration, for first flight on Artemis IV.

Exploration Research and Development. For FY2022, the Administration is requesting $2.4 billion, an increase of $424 million (21.5%) over the FY2021 appropriation, to develop the technologies and systems required for deep space, cislunar, and lunar surface activities under the Exploration Research and Development (ERD) theme. The proposed budget increase would continue the development of a Human Landing System (HLS) carried out as a public-private-partnership that would transport astronauts to and from the lunar surface in the Artemis III mission with a goal of 2024, as stated in the Congressional Justification document. NASA established HLS as a formal program in FY2021, and proposed $1.2 billion for the program in FY2022, an increase of $267 million (28.7%) over the FY2021 appropriation. In April 2021, NASA selected SpaceX to develop and demonstrate an HLS for the Artemis III mission, though work on that award is currently on hold pending review of bid protests filed with the Government Accountability Office (GAO). The total runout for HLS over the FY2021-FY2026 budget horizon would be $8.7 billion.

The FY2022 request proposes $91.5 million for Advanced Cislunar and Surface Capabilities to support formulation of lunar surface logistics systems, including surface mobility (rovers) and habitation systems; $785 million for the Gateway, a human-rated outpost in lunar orbit; and funding for developing and testing high-priority exploration technologies and capabilities;

research and technology development toward protecting and understanding human health and performance in deep space exploration.

Spaceflight Operations

The request for Space Operations (called "LEO and Spaceflight Operations" in the FY2022 request) is $4.02 billion, an increase of $29.2 million (0.7%) above the FY2021 appropriation. The account funds human spaceflight operations in LEO, including activities associated with the International Space Station (ISS).

International Space Station (ISS). The Administration is requesting $1.3 billion for the operation, maintenance, and research conducted aboard the ISS of which $1 billion is for Systems Operations and Maintenance an increase of $34 million (3.4%) over the FY2021 appropriation and $279.4 million is for technology development and basic and applied research, including the ISS National Lab. The FY2022 budget proposal also would transfer demand stimulation activities—those activities intended to develop and mature the demand side of the LEO economy—from the Commercial LEO Development program into the ISS Research account.

Space Transportation. The request includes nearly $1.8 billion to support the safe transport of U.S. astronauts and cargo to and from the ISS under the Space Transportation account, a decrease of $101.2 million (5.4%) from the FY2022 appropriation. Most of the budget, or $1.6 billion ($44.0 above the FY2021 enacted level, an increase of 2.8%), would go toward the Crew and Cargo Program Transportation account, which would fund operational cargo missions under the Commercial Resupply Services contract (CRS-2) (providers: Northrop Grumman, SpaceX, and Sierra Nevada) and commercial crew missions which have begun for SpaceX under the Commercial Crew transportation Capability (CCtCap) contracts. The second provider, Boeing, is scheduled to launch its second uncrewed Orbital Flight Test in July 2021 and the Crewed Flight Test no earlier than the first quarter of FY2022. Once Boeing's vehicle is certified, NASA is planning for a total of at least two commercial crew missions per year.

Space and Flight Support. The Administration is requesting $817.0 million for Space and Flight Support, which provides mission critical space communications, launch and test services, and astronaut training in service of NASA and other government and non-government customer missions using NASA infrastructure.

Commercial LEO Development. The Administration is requesting $101.1 million for the Commercial LEO Development program, an increase of $84.1 million (494.7%) over the FY2021 appropriation. NASA intends to use the Commercial LEO Development program to develop a robust commercial space economy in LEO. Activities supported under this account in 2022, NASA would continue to support the development of "free-flying"—that is, orbiting in LEO separately from the ISS—commercial LEO destinations that will lead to eventual demonstrations. NASA would also continue development of a new commercial segment for the ISS.

Space Technology Mission Directorate

The Administration is requesting $1.43 billion for the Space Technology Mission Directorate (STMD) in FY2022, a $325 million (29.5%) increase over the FY2021 appropriation.

Table 2: STMD Budget ($ millions)

	FY21 Enacted	FY22 Request	Change FY22 - FY21	
			Amount	Percent
NASA Total	**23,271.28**	**24,801.5**	**1,530.22**	**6.6%**
Space Technology Mission Directorate	1,100.0	1,425.0	325.0	29.5%
Early Stage Innovation and Partnerships	117.5	145.0	27.5	23.4%
Technology Maturation	227.1	491.2	264.1	116.3%
Technology Demonstration	528.4	501.8	-26.6	-5.0%
SBIR and STTR	227.0	287.0	60.0	26.4%

Source: NASA, FY2022 Budget Request Congressional Justification

STMD funds critical technology development to support emerging, innovative technologies for exploration, science, and cross-cutting activities within five strategic thrust areas: Go (rapid, safe, and efficient space transportation), Land (expanded access to diverse surface destinations), Live (sustainable living and working farther from Earth), and Explore (transformative missions and discoveries), and Lead (ensuring American global leadership in space technology).

Early Stage Innovations and Partnerships. Within the Early Stage Innovations and Partnerships Program (ESIP), NASA funds concepts studies, applied research, and early technology development, with an emphasis on identifying emerging concepts and technologies that support NASA's long-term objectives in robotic and human exploration of space. In FY2022, the administration is proposing $145 million for ESIP, an increase of $27.5 million, or 23.4%, over the FY2021 appropriation. Of that increase, NASA would spend at least $10 million to support climate research and clean energy economy investments.

Technology Maturation. The STMD Technology Maturation program focuses on technologies beyond early stage research, but not yet at the level of flight demonstration, that fulfill the needs of multiple stakeholders, which include NASA's mission directorates, commercial partners, and other government agencies. In FY2022, the administration is proposing $264.1 million for Technology Maturation, an increase of $264.1 million, or 116.3%, over the FY2021 enacted level. According to the Congressional Justification, in FY2022, NASA would introduce a new Industry and Commerce Innovation Opportunity to provide open topic calls for industry to identify and propose activities to further enable commercial development of key technologies.

Technology Demonstration. Under the Technology Demonstration program, STMD proposes to conduct ground-based and space-based testing and demonstrations to transition new technologies to NASA exploration missions, as well as potentially on to industry or other federal agencies. Major projects within Technology Demonstration portfolio include the Restore and SPIDER On-orbit Servicing, Assembling, and Manufacturing 1 (OSAM-1) mission, the Laser Communications Relay Demo, Solar Exploration Propulsion, the Flight Opportunities program,

and Small Spacecraft Technology. The FY2022 budget proposal does not support any nuclear propulsion technology demonstration activities; in FY2021, nuclear propulsion was appropriated $110 million.

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR). STMD manages the agency's federal SBIR and STTR programs in support of NASA's missions.

Science Mission Directorate

The Administration is requesting $7.9 billion for the Science Mission Directorate (SMD), an increase of $630.6 million (8.6%) from the FY2021 appropriation.

Table 3: NASA SMD Budget ($ millions)

	FY21 Enacted	FY22 Request	Change FY21 - FY20	
			Amount	Percent
NASA Total	**23,271.28**	**24,801.5**	**1,530.22**	**6.6%**
Science Mission Directorate	7,300.8	7,931.4	630.6	8.6%
Earth Science	2,000.0	2,250.0	250.0	12.5%
Planetary Science	2,699.8	3,200.0	500.2	18.5%
Astrophysics	1,356.2	1,400.2	44.0	3.2%
James Webb Space Telescope	414.7	175.4	-239.3	-57.7%
Heliophysics	751.0	796.7	45.7	6.1%
Biological and Physical Sciences	79.1	109.1	30.0	37.9%

Source: NASA, FY2022 Budget Request Congressional Justification

NASA SMD focuses on three overarching objectives: discovering the secrets of the Universe, searching for life in the Solar System and beyond, and protecting and improving life on Earth. SMD pursues its objectives within and across its five discipline divisions: Earth Science, Planetary Science, Astrophysics, Heliophysics, and Biological and Physical Sciences, and is guided by the current science plan[4] and the priorities and recommendations of National Academies "decadal surveys". Each Division funds research, development and operation of flight missions, data management systems, and technology development programs.

Earth Science. The Administration is requesting $2.25 billion for Earth Science, an increase of $250 million (12.5%) from the FY2021 enacted appropriation. The request supports initiating the next-generation Earth System Observatory by formally commencing development of all four large Designated Observable—top-recommended observation or measurement--missions, prioritized in the 2018 Decadal Survey, in FY2022 and establishing the Earth Science Explorer program for small- to mid-size missions led by principle investigators. In addition, The request supports continuing work on many missions already in development, including the Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE) mission, the Climate Absolute Radiance and

[4] NASA, "Science 2020-2024: A Vision for Science Excellence." Available at: https://science.nasa.gov/science-pink/s3fs-public/atoms/files/2020-2024_Science.pdf.

Refractivity Observatory (CLARREO) Pathfinder mission, Landsat-9, NASA-ISRO Synthetic Aperture Radar (NISAR), and the Surface Water and Ocean Topography (SWOT) mission.

The budget proposal also includes $72.7 million for the Applied Sciences Program, an increase of $9.8 million (15.6%) over the FY2021 enacted level. The Applied Science Program supports the use of scientific results and satellite observations for practical use by public and private sector organizations, and the increase in FY2022 would support a new Application and Research Team focused on science-informed solutions to addressing climate impacts, as well as new efforts to support climate and environmental resilience activities, including specific activities on wildfire forecasting, renewable energy, building energy efficiency, and agricultural needs.

Planetary Science. The President's FY2022 budget requests $3.2 billion for the Planetary Science Division, an increase of $500 million (18.5%) from the FY2021 enacted level. The budget request supports the continued development of the Mars Sample Return mission, with a launch readiness date of no earlier than 2026. Planetary Science also funds missions and research related to planetary defense, the identification, characterization, and possible mitigation of asteroids and comets that are potentially hazardous to Earth.

Within the Planetary Science Division, the Lunar Discovery and Exploration Program (LDEP). which is part of the Agency's Artemis Moon to Mars exploration initiative, is proposed for $451.5 million in FY2021, an increase of $53.8 million (12.1%) over the FY2021 appropriation. The request includes Commercial Lunar Payload Delivery Service (CLPS) contracts—lander services to deliver NASA-funded science payloads to the lunar surface—and development of small satellites, instruments, and other activities and payloads that serve scientific, exploration, and resource utilization needs, including the Volatiles Investigating Polar Exploration Rover (VIPER).

Astrophysics. The Administration's FY2022 budget request for the Astrophysics Division is $1.4 billion, a $44 million (3.2%) increase from the FY2021 enacted level. The request would provide full funding for the development of the Nancy Grace Roman Space Telescope (formerly WFIRST) and a number of operating telescopes, including the Hubble Space Telescope, Chandra X-ray Observatory, and the Transiting Exoplanet Satellite Survey mission. The request proposes to terminate operations of the Stratospheric Observatory for Infrared Astronomy (SOFIA), which has been funded annually at $85 million, due to its high cost relative to its scientific productivity.

James Webb Space Telescope (JWST). The Administration is requesting $175.4 million for the development of JWST, which would continue to follow the rebaselined budget profile established in 2018. JWST's current development cap is $8.8 billion and lifecycle cost of $9.7 billion. The budget supports the October 2021 launch readiness date determined after a schedule risk assessment was conducted in June 2020 to evaluate the impacts of COVID-19 and technical challenges.[5] JWST is managed as a separate program and budget line independent of the Astrophysics Division, which has been the case since FY2011 as a way to improve oversight and control of the project.

[5] https://www.nasa.gov/press-release/nasa-announces-new-james-webb-space-telescope-target-launch-date.

Heliophysics. The Administration is requesting $796.7 million for the Heliophysics Division, an increase of $45.7 million (6.1%) from the FY2021 appropriation. The Heliophysics Division supports efforts to improve our understanding of the Sun, the Sun-Earth connection and its implication for life on Earth, and the Sun's interaction with the rest of the Solar System and beyond. In FY2022, the proposed budget would support the development of the next Living with a Star mission, the Geospace Dynamics Constellation (GDC), a decadal survey priority. The Space Weather Science and Applications program, within the Heliophysics Divison's Living With a Star program, supports the transition of heliophysics results, technologies, and tools to the space user community to address the impacts of space weather, and the program is proposed for $9.9 million in FY2022, a decrease of $15.1 million (60%).

Biological and Physical Sciences. The Biological and Physical Sciences (BPS) Division supports the study of biological and physical systems under extreme environmental conditions found in space that was previously funded in HEOMD under the Space Life and Physical Sciences Research and Applications program. In FY2021, NASA moved that research to SMD and established the new BPS Division. The FY2022 request proposes $109.1 million for BPS, an increase of $30 million (37.9%). The request for BPS would support plans for a "major shift in research strategy from a broad to a focused portfolio" with a focus on investments in three research areas: Thriving In Deep Space (TIDES), Quantum Physics, and Soft Matter.

Aeronautics Research Mission Directorate

The Aeronautics Research Mission Directorate (ARMD) FY2022 budget request is $914.8 million, an $86.1 million (10.4%) increase over the FY2021 appropriation. According to the Congressional Justification document, the increase to ARMD's budget would accelerate key components of the Sustainable Flight National Partnership (SFNP), which will demonstrate multiple technologies for the next-generation single-aisle aircraft, which is targeting deployment in the early 2030s with at least 25% better fuel efficiency than today. The SFNP will feature a full-scale sustainable flight demonstrator (X-plane) to validate an integrated system of advanced, more efficient power and propulsion technologies for the engine and aircraft design and manufacturing. In FY2022, the increased funding would accelerate the sustainable flight demonstrator, electrified powertrain flight demonstrations, subsonic technology research, aircraft operations, and university research into net-zero carbon emissions aviation technologies.

Table 4: ARMD Budget ($ millions)

	FY21 Enacted	FY22 Request	Change FY21 - FY20	
			Amount	Percent
NASA Total	**23,271.28**	**24,801.5**	**1,530.22**	**6.6%**
Aeronautics Research Mission Directorate	828.7	914.8	86.1	10.4%
Airspace Operations and Safety Program	92.0	104.5	12.5	13.6%
Advanced Air Vehicles Program	211.4	243.7	32.3	15.3%
Integrated Aviation Systems Program	278.7	301.5	22.8	8.2%
Transformative Aero Concepts Program	129.7	148.0	18.3	14.1%
Aerosciences Evaluation and Test Capabilities	116.9	117.0	0.1	0.1%

Source: NASA, FY2022 Budget Request Congressional Justification

ARMD is guided by a Strategic Implementation Plan,[6] which has identified six research thrusts for the program: Safe, Efficient Growth in Global Operations; Innovation in Commercial Supersonic Aircraft; Ultra-Efficient Subsonic Transports; Safe, Quiet, and Affordable Vertical Lift Air Vehicles; In-Time System-Wide Safety Assurance; and Assured Autonomy for Aviation Transformation. The FY2022 ARMD budget would support four programs: the Airspace Operations and Safety Program, which focuses research on the safe and efficient growth of global operations; the Advanced Air Vehicles Program, which conducts research on ultra-efficient vehicles, the Integrated Aviation Systems Program (IASP), which carries out integrated system-level research and technology, the Transformative Aero Concepts Program, which supports high-risk research across multiple strategic thrust areas for ARMD; and the Aerosciences Evaluation and Test Capabilities (AETC) account, which manages aerospace facilities, such as wind tunnels, for the entire agency.

Within IASP, NASA's FY2022 budget request proposes $91.2 million for the Electrified Powertrain Flight Demonstration (EPFD) to expand to two major awards, as well as the initiation of the sustainable flight demonstrator, targeting first flight in FY2026. The FY2022 request would support continuation of the Low Boom Flight Demonstrator (LBFD), which is an experimental aircraft (X-plane) development program managed under both AAVP (flight research) and IASP (development and operation of vehicle). As part of the LBFD program, the X-59 QueSST aircraft mission will provide data to federal and international regulators and standards-setting bodies to support quiet supersonic overland flight.

The FY2022 request would also support testing and integration of electric propulsion components and systems, fundamental research on hypersonics, the safe integration of the rapidly increasing number of autonomous aircraft into the National Airspace System, and the University Leadership Initiative.

Office of STEM Engagement

In the FY2022 budget proposal, the administration is proposing to fund the Office of STEM Engagement at $147 million, an increase of $20 million (15.7%) over the FY2021 appropriation.

Table 5: Office of STEM Engagement Budget ($ millions)

	FY21 Enacted	FY22 Request	Change FY22 - FY21	
			Amount	Percent
NASA Total	**23,271.28**	**24,801.5**	**1,530.22**	**6.6%**
Office of STEM Engagement	127.0	147.0	20.0	15.7%
National Space Grant College and Fellowship Program	51.0	57.0	6.0	11.8%
Established Program to Stimulate Competitive Research	26.0	26.0	0.0	0%
Minority University Research and Education Project	38.0	48.0	10.0	26.3%
Next Gen STEM	12.0	16.0	4.0	33.3%

Source: NASA, FY2022 Budget Request Congressional Justification

[6] Available at: https://www.nasa.gov/aeroresearch/strategy.

As noted in the table above, the request proposes increases for the Next Gen STEM project to support K-12 formal and informal learner engagement; for Space Grant, to increase partnerships with NASA's mission directorates; and for the Minority University Research and Education Project (MUREP), to enable greater connections with Minority Serving Institutions and to establish new high school bridge programs and fellowships.

Mission Support Directorate

The Administration is requesting $3.5 billion for the accounts managed by the Mission Support Directorate (MSD) to provide the support, infrastructure, and capabilities to enable the agency's portfolio of missions.

Table 6: MSD Budget ($ millions)

	FY21 Enacted	FY22 Request	Change FY22 - FY21	
			Amount	Percent
NASA Total	**23,271.28**	**24,801.5**	**1,530.22**	**6.6%**
Mission Support Directorate	**3,365.0**	**3,439.5**	**74.5**	**2.2%**
Safety, Security, and Mission Services	2,936.5	3,049.2	112.7	3.8%
Mission Services and Capabilities	1,918.3	2,028.80	110.5	5.8%
Engineering, Safety, and Operations	1,018.2	1,020.40	2.2	0.2%
Construction & Environmental Compliance & Restoration	428.5	390.3	-38.2	-8.9%
Construction of Facilities	370.4	315.6	-54.8	-14.8%
Environmental Compliance and Restoration	58.1	74.7	16.6	28.6%

Source: NASA, FY2022 Budget Request Congressional Justification

Safety, Security, and Mission Services

The Administration is requesting $3 billion for Safety, Security, and Mission Services (SSMS) in FY2022, an increase of $75 million (2.2%) over the FY2021 appropriation. SSMS supports capabilities, workforce, and facilities to enable NASA operations and missions. The SSMS budget was reorganized in FY2021 into two new themes, Mission Services and Capabilities (MSaC) and Engineering, Safety, and Operations (ESO). Under the MSaC theme, NASA manages three enterprise service programs: Information Technology, Mission Enabling Services (agency-wide business operations and mission support), and Infrastructure and Technical Capabilities (facilities sustainment, operations, and maintenance and technical capabilities).

Construction and Environmental Compliance and Restoration

The Administration is requesting $390 million for Construction and Environmental Compliance and Restoration (CECR) in FY2022, a decrease of $166 million (44%) over the FY2020 appropriation.

Construction of Facilities (CoF). CoF is a capital fund for repairs and improvements to NASA infrastructure and facilities. More than 83% of NASA's constructed infrastructure is beyond its design life.

Environmental Compliance and Restoration (ECR). NASA is proposing $74.7 million for ECR in FY2022, an increase of approximately $17 million (28.6%) over the FY2021 appropriation to continue to meet all legal obligations associated with hazardous material and waste products released to the surface or groundwater at NASA installations, NASA-owned industrial plants supporting NASA activities, current or former sites where NASA operations have contributed to environmental problems, and other sites. The largest project in the ECR portfolio continues to be the remediation and cleanup activities at the Santa Susana Field Laboratory site in California.

Inspector General

The Administration has requested $46.0 million in FY2022 for the Office of the Inspector General (OIG). The FY2022 request is $1.8 million (4.1%) above the FY2021 appropriation, to support expanded activities related to the agency's Artemis effort. The Administration is also requesting that the entire OIG budget be in the form of two-year funding.

Table 7: OIG Budget ($ millions)

	FY21 Enacted	FY22 Request	Change FY22 - FY22	
			Amount	Percent
NASA Total	**23,271.28**	**24,801.5**	**1,530.22**	**6.6%**
Inspector General	44.2	46.0	1.8	4.1%

Source: NASA, FY2022 Budget Request Congressional Justification

Chairwoman JOHNSON. Now the hearing will come to order and, without objection, the Chair is authorized to declare recess at any time. Before I deliver my opening remarks, I just want to say that, since we are in person and virtual today, I am delighted. It's been a while since we've been here, and I hope that we will continue to expand as we move along. Couple of reminders, though. Members and staff who are attending in person, and are unvaccinated against COVID–19, must stay masked throughout the hearing. Unvaccinated Members may remove their masks only during the question and answer, the 5-minute rule. And you're on your own to make that determination. Members who are attending virtually should keep their video feed on as long as they are present in the hearing, and Members are responsible for their own microphones, so please also keep your microphones muted until you are speaking. And finally, if Members have documents they wish to submit for the record, please e-mail them to the Committee Clerk, whose e-mail address was circulated prior to the hearing.

We have a—we've done that. We want to say welcome, and welcome back to our Administrator. I look forward to working with him, and we are all delighted that we have a person that is familiar with the work of the Committee, and especially the work of space. Senator Nelson served on our Committee. In fact, he chaired the Space Subcommittee for 6 years, during which time that—he flew into space about—aboard the national Space Shuttle Columbia. And now we welcome him back today to testify before our Committee as the National—NASA (National Aeronautics and Space Administration) Administrator after a distinguished career in both the House and Senate. We look forward to his testimony, and welcome again.

It is no secret to our colleagues that I am a strong supporter of NASA. It is one of the crown jewels of our Nation's R&D (research and development) enterprise, and equally importantly, it is a source of inspiration for our young people, and indeed for people young and old around the world. And I'm a Texan, where President Johnson took the lead, and heard the call from President Kennedy to keep going with it. Because NASA turns daring aspirations into reality, whether it is flying a helicopter above the dusty expanses of Mars, or pushing the boundaries of aeronautics research here on Earth, working with 14 other nations to build and operate an International Space Station (ISS) in Earth orbit, or building a fleet of spacecraft to monitor our challenging climate, or searching for life elsewhere in the universe.

I like to say the Science, Space, and Technology Committee is the Committee for the future, and I think that is equally true of NASA. The dedicated men and women of NASA are helping create our future in space and here on Earth, and they should take great pride in both what they have accomplished to date and in what they are striving to accomplish in the days and years ahead. Yet turning NASA's aspirations into reality will take more than determination, or even good budgets. For example, to execute an ambitious national initiative like the Artemis Moon-Mars initiative will require clear goals and objectives, thoughtful planning, realistic scheduling, and a credible organizational and management structure, and at-

tention to the multitude of details that spell the differences between success and catastrophic failure.

And also critical to the success will be finding out as soon as possible where the problems are that need attention. That is why I have argued that it is an early priority to carry out an independent review of the entire Artemis initiative so that you can take whatever corrective actions we need as soon as possible. The lessons of the past are clear. Failing to uncover problems because of arbitrary schedule pressure inevitably winds up costing more in both money and delays, and increased risk. If Congress is going to be asked to provide increased funding, it first will need to have confidence in NASA's initiatives, and it is critical that we see a path to success. Another issue needing attention in the future of this International Space Station. It will not last forever. We need to know how long it will remain viably, structurally, and operationally. We need a clear plan for transitioning to what comes next, and we need to know what the future of the United States and its international partners in Low Earth Orbit should be, especially given the reality of the new Chinese space station.

I could go on, but as I said, these are very challenging times for NASA. However, make no mistake, the Committee wants NASA to succeed. I hope that today's hearing will be just the start of a continuing dialogue and collaboration with you, Mr. Administrator, and with that, I want to again welcome you, and look forward to your testimony.

[The prepared statement of Chairwoman Johnson follows:]

Good morning, and welcome back, Mr. Administrator. I say welcome back, because when he was first elected to Congress, Senator Nelson served on our Committee. In fact, he chaired the Space subcommittee for six years, during which time he flew into space aboard the Space Shuttle Columbia.

And now we welcome him back today to testify before our Committee as NASA Administrator after a distinguished career in both the House and the U.S. Senate. We all look forward to your testimony, Mr. Administrator.

It is no secret to my colleagues that I am a strong supporter of NASA. It is one of the crown jewels of the nation's R&D enterprise, and equally importantly, it is a source of inspiration for our young people, and indeed for people young and old around the world. Because NASA turns daring aspirations into reality, whether it is flying a helicopter above the dusty expanses of Mars, pushing the boundaries of aeronautics research here on Earth, working with 14 other nations to build and operate an international space station in Earth orbit, building a fleet of spacecraft to monitor our changing climate, or searching for life elsewhere in the universe.

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Yet turning NASA's aspirations into reality will take more than determination or even good budgets. For example, to execute an ambitious national initiative like the Artemis Moon-Mars initiative will require clear goals and objectives, thoughtful planning, realistic scheduling, a credible organizational and management structure, and attention to the multitude of details that spell the difference between success and catastrophic failure.

And also critical to Artemis' success will be finding out as soon as possible where the problems are that need attention. That is why I have urged that it be an early priority to carry out an independent review of the entire Artemis initiative so that you can take whatever corrective actions are needed as soon as possible.

The lessons of the past are clear: failing to uncover problems because of arbitrary schedule pressure invariably winds up costing more in both money and delays, and in increased risk. If Congress is going to be asked to provide increased funding for Artemis, it first will need to have confidence that NASA's initiative is on a credible path to success.

Another issue needing attention is the future of the International Space Station. It will not last forever. We need to know how long it can remain viable structurally and operationally. We need a clear plan for transitioning to what comes next, and we need to know what the future of the United States and its international partners in Low Earth Orbit should be, especially given the reality of the new Chinese space station.

I could go on, but as I said, these are very challenging times for NASA. However, make no mistake-this Committee wants NASA to succeed. I hope that today's hearing will be just the start of a continuing dialogue and collaboration with you, Mr. Administrator, and with that, I want to again welcome you, and I look forward to your testimony.

Chairwoman JOHNSON. The Chair now recognizes my outstanding Ranking Member, Mr. Lucas.

Mr. LUCAS. Thank you, Madam Chair, and before I start, I want to thank you for holding this hybrid hearing, and enabling Members, staff, and Administrator Nelson to participate in person safely. After a year and a half of virtual hearings, I think I speak for the entire Republican Conference when I say it's good to be back doing the people's business in person. So thank you, Madam Chair.

Today's hearing is important and timely. For several years NASA's conducted review after review of human space flight program. Although the overall goal to return U.S. astronauts to the Moon remains constant, NASA's changed its plans on how to accomplish that goal several times over numerous reviews. After numerous independent advisory groups, like the National Academies of Science, and the Aerospace Safety Advisory Panel, have highlighted, program stability is critical to ensuring overall mission success.

As Administrator Nelson knows, Congress has provided this consistency for nearly 20 years following the Columbia accident investigation, the cancellation of the shuttle, and the development of deep space capacities. Despite the ebbs and flows of each new administration's priorities, Congress has maintained a steady course to the Nation's space program. That's why I was pleased to see that the Biden Administration is continuing the Artemis Program. Keeping our sights on returning to the Moon in a manner that enables exploration to Mars, and beyond, is paramount at this critical juncture. The Orion spacecraft was delivered to the Kennedy Space Center last year, and the space launch system was also recently delivered to Kennedy Space Center after a successful green run. It's exciting to see the SLS (Space Launch System) being stacked with boosters in the vehicle assembly building (VAB) as we speak.

NASA's exploration ground systems are working diligently to receive, process, and launch these critical national systems, but more work remains. NASA's human landing system (HLS) procurement is stalled by GAO (Government Accountability Office) protests. Everyone wants to get started on this critical piece of hardware, but we must first let the process play out, and adjust course based on GAO's ruling and available funding. I look forward to working with our colleagues in the Senate, and on the Appropriations Committees, and in the administration to chart a path forward that enables the success of our space program.

The largest unknown looming on the horizon is the budget. Finding an extra $10 billion for the human landing system is no easy task. While the Senate recently authorized an additional $10 billion, and required NASA to select an additional contractor, if NASA

doesn't get additional appropriated funding, this could become an unfunded mandate that could end up with NASA having to cut billions of dollars from other programs. I'm sure no one wants to see this happen. That's why it's important for NASA to propose realistic plans, budgets, and schedules, and not rely on Hail Mary passes to save the day. Other nations, like China, are making slow and steady progress, and are following disciplined plans. We must maintain steady support for our national space program so that the new frontiers in space will be explored by free nations, not by oppressive regimes.

With that, Madam Chair, it is wonderful to be at the dais with you, and I yield back.

[The prepared statement of Mr. Lucas follows:]

Before I start, I would like to thank Chairwoman Johnson for holding this hybrid hearing and enabling Members, staff, and Administrator Nelson to participate in person safely. After a year and a half of virtual hearings, I think I speak for the entire Republican conference when I say that it is good to be back doing the people's business in person - so thank you.

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But more work remains. NASA's Human Landing System procurement is stalled by GAO protests. Everyone wants to get started on this critical piece of hardware, but we must first let the process play out and adjust course based on the GAO's ruling and available funding. I look forward to working with our colleagues in the Senate, on the Appropriations Committees, and in the Administration to chart a path forward that enables the success our space program.

The largest unknown looming on the horizon is the budget. Finding an extra $10 billion for the Human Landing System is no easy task. While the Senate recently authorized an additional $10 billion and required NASA to select an additional contractor, if NASA doesn't get additional appropriated funding, this could become an unfunded mandate that could end up with NASA having to cut billions of dollars from other programs. I am sure no one wants to see this happen. That's why it's important for NASA to propose realistic plans, budgets, and schedules and not rely on "Hail Mary Passes" to save the day.

Other nations, like China, are making slow and steady progress and are following disciplined plans. We must maintain steady support for our national space programs so that new frontiers in space are explored by free nations, not oppressive regimes.

Chairwoman JOHNSON. Thank you very much. At this time I'd like to introduce our witness. Senator Bill Nelson was sworn in as the 14th NASA Administrator May the 3rd, 2021. He is no stranger to this Committee, and Congress, having chaired the Space and Aeronautics Subcommittee for six years, and later serving as the Ranking Member on the State Commerce, Science, and Transportation Committee in the Senate. He's served in the House for 13 years, and was later elected three times to the U.S. Senate, rep-

resenting Florida for 18 years. Senator Nelson attended the University of Florida and Yale University. He received a J.D. from the University of Virginia. After law school, he served on active duty as Captain in the U.S. Army. He has served in public office over four decades, in the State Legislature, as a State Treasurer, and in the U.S. Congress. In 1986, he flew on Space Shuttle Columbia as a payload specialist, orbiting the Earth 98 times over six days, while conducting research experiments. After leaving the Senate, he continued to be engaged in NASA activities, serving on the NASA Advisory Council, until his nomination of the NASA Administrator. We are delighted to have him here today, Administrator Nelson, and we look forward to your testimony.

Our witnesses should know you will have five minutes for the spoken testimony. Your written testimony will be included in the record for the hearing, and when you have completed your spoken testimony, we'll begin with questions. Each Member will have five minutes to ask the question. So now, Administrator Nelson, you're recognized.

TESTIMONY OF THE HONORABLE BILL NELSON, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Mr. NELSON. Thank you, Madam Chair. If it looks like I'm smiling, I am. Coming back into these halls brings back so many pleasant memories, and so many cherished friendships. Most of these portraits of people I have served with, and it—it's an outstanding Committee. I want to welcome the new Member of Congress, and, Madam Chair, if you're getting folks that are so experienced like your new Member coming from Sandia, again, it's just an example of the reputation of the Members of this Committee to be a very well experienced and very serious Committee.

We're going back to the Moon in preparation to go to Mars, and space is hard. A lot of people focus in on the date, about 2024. We're going back to the Moon with humans in 2023. It's going to be following the first launch, which is at the end of this year, 2021. The largest, most powerful rocket ever, the SLS Space Launch System. We are then going to hitch up with whoever is the winner of all the competitions after the GAO makes its decision, and we are in a blackout period now until August the 4th, when the GAO is going to determine whether or not the bid protest is successful. All of this occurred before I was there, but I'm here to defend what NASA has done, but with regard to what's going forward, we're not going to know until August the 4th, when the GAO decides. Pam Melroy, who I just swore in on Monday, now is with us as our deputy. Our No. 3 in the agency is Bob Cabana, also an astronaut commander, as is Pam. He's long experienced in the administration in Johnson, then the head of Stennis, then the head of Kennedy, and well respected, and the three of us already trying to make the plan so that when the GAO decides that we can move out quickly, depending upon what the GAO decides as a legal matter.

Now, that's just the human exploration. Look what's already happened. What American is not excited about Perseverance, and little Ingenuity flying around all over the Mars surface? Again, a pinpoint landing. But remember, as the Ranking Member said, re-

member, it was followed by only the second Nation to be able to land a rover successfully. The Chinese government, the Chinese Space Program did that, and they have a very aggressive program, and we've got to beware of that. They're putting a series of landers on the south pole of the Moon. So are we. It's called the CLPS (Commercial Lunar Payload Services) Program. It's—the C stands for commercial. We're going to go down there to the south pole why? Because there's water down there, and it's frozen. And when you have water, that means you've got oxygen, and you've got fuel, hydrogen. So both of our nations are going down there, but the fact that they are planning this, just beware.

Look at what's happening in the Earth science and the planetary science. We just announced two missions that are going to go to Venus. We haven't been to Venus in 30 years. Why Venus? You think of it, the Sun, the next planet is Mercury, it's hot. The next planet is Venus, and it's covered with a shroud of clouds, and that's caused it to heat up so much that it can melt lead on the surface. The next planet is Earth. It has a habitable atmosphere. The next planet is Mars, and it has a very thin atmosphere. Now, what is it about Mars, and about Venus? Do they have the chemical compositions that they could've had life? Because, after all, this universe has been developing for 13–1/2 billion years.

And I'll conclude with this, Madam Chair. Another part of our science, we're sending up, in November, this telescope. It's going out of French Guiana on an Ariane rocket. It's about a $9 billion telescope, and it is going to peer back to the light source 13.35 billion years. That's only 150 million years after the Big Bang, which is the beginning of the very cosmic systems. And we're going to be able to capture that light that has been traveling all those billions of years, and find out things that we never found out before. We found out a lot from Hubble, which is still up there trying to work. That's the excitement of what is going. And finally, Madam Chairman, Earth science. In every one of your pockets is that cell phone, which I forgot to turn off, and it has a camera that we all use. That camera is on a chip, and that camera was developed by NASA to observe the Earth, to get the precision measurements because of what's happening to our planet. If you want to mitigate the climate, you've got to measure it, and that's what NASA does. Thank you, Madam Chair.

[The prepared statement of Mr. Nelson follows:]

National Aeronautics and
Space Administration

Hold for Release Until
Presented by Witness

June 23, 2021

Committee on Science, Space, and Technology

U.S. House of Representatives

Statement of:
The Honorable Bill Nelson
Administrator

117th Congress

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UNTIL PRESENTED
BY WITNESS
June 23, 2021

Statement of

The Honorable Bill Nelson
Administrator
National Aeronautics and Space Administration

before the

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

Chairwoman Johnson and Members of the Committee, I am pleased to have this opportunity to discuss NASA's FY 2022 budget request of $24.8 billion. This request represents an increase of $1.6 billion, or 6.6 percent, above the FY 2021 enacted level.

I would like to thank the Committee for its ongoing bipartisan support for NASA. NASA and the Committee have come together to forge a durable national consensus on a balanced program for NASA, including strong budgets for all of the Agency's activities. Building on this support, the budget request includes expanded climate change research; continued investment in human spaceflight through the International Space Station (ISS) and Artemis Programs that enhance global engagement and diplomacy; investments in cutting-edge research and development that fuel innovation, create high-paying jobs, grow the economy, and improve life on Earth; advancement of the U.S. aviation industrial base to build a green aviation system; and strengthening of a diverse Science, Technology, Engineering, and Math (STEM) workforce that inspires future generations.

NASA is more than the world's premier space exploration organization. NASA is a uniquely powerful source of national inspiration and international leadership. Over the past year, the NASA team has demonstrated remarkable resilience, overcoming COVID-19 challenges to press forward with a series of outstanding successes, including the historic first flight on another planet. NASA's landing of Perseverance on Mars is emblematic of an Agency, and a Nation, that can overcome challenges, to achieve whatever goals we set. To quote the President on a phone call to NASA Jet Propulsion Laboratory (JPL):

> "We can land a rover on Mars. We can beat a pandemic. And with science, hope, and vision, there's not a damn thing we can't do as a country."

With the resources entrusted to us by Congress and the American people, and the dedicated efforts of our commercial partners, we have returned human spaceflight to American soil on American rockets. Adapting what we have learned from these efforts, we are moving rapidly to return Americans to the surface of the Moon as quickly as we can safely do so. We are committed to landing the first woman and the first person of color on the Moon. We will use all of this Nation's capacity for innovation to develop the experience and capability around the Moon that will send Americans on to Mars. We are building the Space Launch System (SLS) and the Orion crew vehicle, to make deep space exploration possible, and we will soon launch the first, uncrewed mission in the Artemis lunar exploration program. During this flight,

targeted for this year, the spacecraft will fly farther than any spacecraft built for humans has ever flown. The budget request includes funding for the development of the Block 1B variant of SLS as well as funding for construction of a second Mobile Launcher, both of which will help support a robust Moon to Mars program.

On April 16, 2021, NASA announced it had selected SpaceX to continue development of the first commercial human lander that will safely carry the next two American astronauts to the lunar surface. The firm-fixed price, milestone-based contract total award value is $2.89 billion, out of total requested five-year Human Landing System (HLS) funding of $7.8 billion. This HLS contract award is under protest as of this time. While the human landing demonstration award is under protest, NASA is continuing to prepare for competition for the follow-on landings to the lunar surface. These services will provide human access to the lunar surface using the Gateway on a regularly recurring basis beyond the initial crewed demonstration mission. By taking a collaborative approach in working with industry and international partners while leveraging NASA's proven technical expertise and capabilities, we will return American astronauts to the Moon's surface once again, this time to explore new areas for longer periods of time.

For over 20 years, NASA has maintained a continuous human presence in Earth orbit, developing technology, skills, and knowledge needed for human exploration of the Moon and Mars. The budget request ensures that there will be no gap in human presence in Low Earth Orbit (LEO) by continuing to invest in commercial LEO destinations and services. The coming year will see a second commercial partner demonstrate crew transportation and begin regular crewed flights to the ISS. This regular cadence of crew rotation missions will contribute to the foundation of a more affordable and sustainable future for American human spaceflight. In addition, this will allow more capacity and resources for research and development projects on ISS, which are improving life on Earth and proving out the viability of a LEO economy.

NASA is on Mars now and studying the planet more intensively than ever before. The request includes funding to develop the mission that will return samples from Mars to Earth. With the successful landing of the Perseverance rover, we are now operating two rovers, a lander, and a helicopter on the surface of Mars, supported by an array of orbiting spacecraft. We continue to operate a constellation of spacecraft exploring the solar system while developing new missions to Earth's Moon and Jupiter's moon Europa, as well as a mission dedicated to detecting potentially hazardous Near-Earth Objects (NEOs). Later this year, we will launch the Lucy mission to explore the Trojan asteroids in the vicinity of Jupiter, to be followed in 2022 by the Psyche mission to a metallic asteroid. These asteroids are thought to be remnants of the primordial material that formed the outer planets. NASA recently announced a major return to our nearest planetary neighbor, Venus, selecting not one but two missions that will be run out of the Planetary Missions Program Office at Marshall Space Flight Center. The first mission, DAVINCI+, will measure the composition of Venus' atmosphere to understand how it formed and evolved, as well as determine whether the planet ever had an ocean. The second mission, VERITAS, will map Venus's surface to determine the planet's geologic history and understand why it developed so differently than Earth.

NASA is a critical piece of the Administration's efforts to understand and address global climate change. The request supports the continued development of high-priority missions including Plankton, Aerosol, Cloud, ocean Ecosystem (PACE); Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder; and Landsat 9, while also supporting acquisition of Earth Science observation data for commercial SmallSat constellations. In a major step forward for Earth Science, we have initiated a mission concept for NASA's Earth System Observatory, a new architecture for deploying and integrating next-generation spaceborne Earth observation systems. The Observatory includes development of four core strategic missions for launch this decade, and will provide the world an unprecedented understanding of the critical interactions between Earth's atmosphere, land, ocean, and ice processes. These processes

define how the changing climate will play out at regional and local levels, and on near- to long-term time scales. The Earth System Observatory builds on NASA's Earth Science Division's current observations of Earth on a global scale, a fleet of 16 major Earth observatories plus six Earth observation instruments on the ISS, SmallSats, CubeSats, and missions flown by piloted and unpiloted aircraft.

Later this year, NASA will launch the James Webb Space Telescope (Webb), the largest and most complex space science observatory ever built. Webb is an infrared telescope designed to observe the farthest objects, broadening and transforming our understanding of the early universe. It will see the light from the first galaxies that formed in the early universe after the Big Bang, and observe the birth of stellar systems, as well as explore distant worlds and study the atmospheres of planets orbiting other stars – known as exoplanets – searching for chemical fingerprints of habitability. Webb will join a constellation of operating astrophysics observatories including the Hubble Space Telescope, Chandra X-Ray Observatory, and seven other operating missions. The request supports the development of the Nancy Grace Roman Space telescope, designed to unravel the secrets of dark energy and dark matter, and to search for and image exoplanets.

Supporting all of these efforts, NASA is developing new technologies ranging from robotic servicing technology to extend the life of orbiting spacecraft to laser communications for space. Launching this year, the Laser Communications Relay Demonstration will showcase the unique capabilities of optical communications to radically increase the volume of information a signal can carry. In FY 2022, NASA will deliver the Polar Resources Ice Mining Experiment-1 to Intuitive Machines, who will transport this first-of-its-kind, *in situ* resource utilization demonstration to the Moon. This experiment will robotically sample and analyze ice from below the surface and study the drill cuttings for water and other chemical compounds to help scientists understand the potential of using resources found on the Moon. The Low-Earth Orbit Flight Test of an Inflatable Decelerator will complete fabrication of its flight hardware for an FY 2022 demonstration of space braking technology that will enable a variety of proposed NASA missions to destinations such as Mars, Venus, and Titan, as well as return to Earth. The On-orbit Servicing, Assembly, and Manufacturing-2 project is working toward a late 2022 launch to build, assemble, and deploy its own operational solar arrays in space. NASA is continuing to spur a vibrant space economy through a new Industry and Commerce Innovation opportunity that will invest in technologies needed by commercial space stakeholders.

NASA's aeronautics research will make significant contributions to the national effort to address global climate change, through vehicle technology development and advanced airspace operations, as well as serving as a vital source of innovation for the country's leading export industry, commercial aviation. The request increases funding for planned green aviation initiatives across these programs and supports the continued development of the X-59 Low Boom Flight Demonstrator, as well as early designs of a Sustainable Flight Demonstrator. This year, we will fly the first test flight of the X-57 Maxwell, NASA's first all-electric X-plane – a major step forward in efforts to develop a more sustainable aeronautics industry.

For the first time in many years, NASA's budget request includes funding for its Office of STEM engagement. With a significant increase over recent appropriated funding, the budget request for STEM engagement will increase investment in the Nation's next generation of scientists, engineers, technologists, mathematicians, and explorers.

NASA is uniquely positioned to support Administration priorities. The Agency is helping to restore America's global standing, demonstrating the power of a diverse, unified democracy to overcome challenges and achieve great goals. As a source of innovation, and by directly promoting the growth of space and aeronautics industries, NASA plays an important supporting role in creating skilled, high-paying jobs. We are critical to the Administration's efforts to expand climate research and investment in

innovative sustainable technologies. In addition, NASA is accelerating efforts to further diversity, equity, and inclusion. NASA has long understood that diversity, equity, and inclusion is not simply a matter of justice or fairness, but rather a source of strength and innovation and critical thinking.

Conclusion

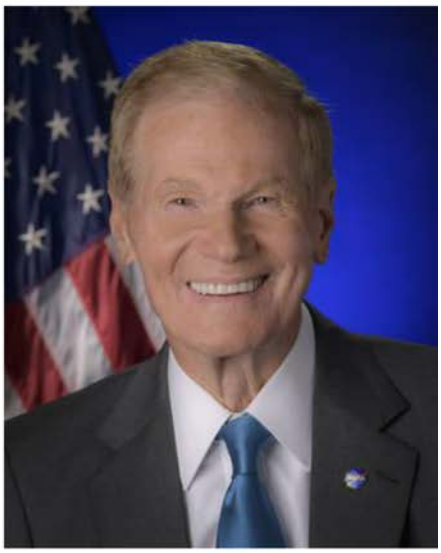
The FY 2022 request demonstrates the President's commitment to NASA and the people across the Agency and its partners who have worked so hard this past year under the most difficult circumstances and achieved unprecedented success. The NASA workforce and the American people should be encouraged by what they see in this budget request. It is an investment in our future, and it shows confidence in the broad array of benefits this Agency delivers for the Nation.

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

NASA Administrator Bill Nelson

Sen. Bill Nelson was sworn in as the 14th NASA administrator on May 3, 2021, tasked with carrying out the Biden-Harris administration's vision for the agency.

Nelson chaired the Space Subcommittee in the U.S. House of Representatives for six years and later served as the Ranking Member on the Senate Commerce, Science, and Transportation Committee, where he was recognized as the leading space program advocate in Congress.



During his time in Congress, Nelson was a strong advocate for NASA's Earth science programs and authored numerous pieces of legislation to combat and mitigate the effects of climate change. Nelson was also a vocal proponent for STEM career training and education programs to create and fill the jobs of the future.

In 2010, Nelson and Sen. Kay Bailey Hutchinson (R-Texas) passed the landmark NASA legislation that mapped out a new future for NASA and set the agency on its present dual course of both government and commercial missions. In 2017, Nelson and Sen. Ted Cruz (R-Texas) authored the NASA Transition Authorization Act of 2017, which expanded NASA's commercial activities in space. After leaving the Senate, Nelson continued to be engaged in NASA activities, serving on the NASA Advisory Council under former Administrator Jim Bridenstine.

From president of 4-H to international president of the Key Club in high school, Nelson has always known the importance of investing in your neighbors and community to create a better future. Nelson continued to serve his community and country while in college at the University of Florida, Yale, and University of Virginia Law School through various service organizations, school leadership positions. He served on active duty as a Captain in the U.S. Army.

Nelson has served in public office over four decades, first in the state legislature and U.S. Congress, then as State Treasurer. He was elected three times to the United States Senate, representing Florida for 18 years. His committees included the breadth of government policy from defense, intelligence and foreign policy to finance, commerce, and health care.

In 1986 he flew on the 24th flight of the Space Shuttle. The mission on Columbia orbited the earth 98 times over six days. Nelson conducted 12 medical experiments including the first American stress test in space and a cancer research experiment sponsored by university researchers.

In 1971, Bill met Grace Cavert of Jacksonville, Florida, while speaking at a statewide young leader convention. Grace has been an active partner in Bill's public service career. From his first race for a seat in the Florida Legislature, Grace has been by his side knocking on doors and talking to folks about issues that mattered to them and their families. They have two grown children, Bill Jr. and Nan Ellen.

Chairwoman JOHNSON. Thank you very much. We now will begin our first round of questions, and I will recognize myself for 5 minutes.

Administrator Nelson, you have often discussed your concerns about China's ambitions and advancements in space, and it is clear that, with sustained planning and methodical preparation, they have made steady and measured progress. They successfully landed on the far side of the Moon, they have returned lunar samples to the Earth, they landed a rover on the surface of Mars, and they are establishing a small space station on Low Earth Orbit. And they indicated that they are planning for human landings and outposts on the Moon. China clearly is in space for the long term, and we need to recognize that and respond accordingly.

To me, that doesn't mean undertaking a crash program with unrealistic timetables, but it does mean that in human spaceflight, NASA needs to focus its efforts, and develop a clear plan and program to achieve these goals set by successive administrations and authorizations, namely return to the Moon as necessary steps toward the ultimate goal of landing humans on Mars. NASA needs to develop that plan and program now, because there aren't unlimited resources, and we really can't afford to pursue nice to have projects at the expense of neglecting essential tasks.

To date the Committee has been—has seen—has not seen such a plan for the Artemis initiative, and it's not because we haven't asked for it. I am not blaming you, because you've just settled in NASA, but what can we expect to see, and when can we expect to see the plan of the program, and how do we get—how are we going to get to Mars, as well as what specifically we will need to accomplish getting to the Moon—on the Moon?

Mr. NELSON. August the 4th, Madam Chairwoman. Once we know the direction legally as a result of GAO, I will have a plan to announce, according to what their decision is, in order to try to have us there as quickly, and as safely, and as efficiently as possible.

Chairwoman JOHNSON. Anything else?

Mr. NELSON. Well, let's be realistic, a lot of people don't know that, for example, what the Source Selection Board, picking out of the existing competitors—NASA had asked for $3.4 billion for that competition. The award of Appropriations was 850 million, and so the Source Selection Board, back before I came in, decided that they didn't have enough money, and that they would award it to one of the three competitors. That award—the concept is that NASA's vehicle, the SLS, with its spacecraft on top, Orion, will take the crew to lunar orbit, and then in lunar orbit there will be the transfer of the crew into the landing vehicle, and that will go down to the surface, they'll do their mission, they'll come back, and then Orion will return with the crew to the Earth. That's one concept. There are other concepts to put up a Gateway, which is a mini space station in lunar orbit, and that is being planned as an international station, that you will take the crew to that. They will then transfer into a lunar landing vehicle. So there are different plans.

What was awarded was just for one demonstration, but there needs to be a landing each year for a dozen years, so there are

many more awards to come if you all decide that it's in the interest of the United States to appropriate that money. And, of course, the appropriation starts right here in this Committee, with the authorizations. So that's about as succinct as I can tell you, Madam Chair.

Chairwoman JOHNSON. Thank you very much. My time is expired. I now recognize Mr. Lucas.

Mr. LUCAS. Thank you, Madam Chair. And continuing with the Chair's line of questioning—and I acknowledge the Chinese are making steady progress on their exploration goals. I think it's very important we maintain our momentum. So, in that vein, I ask you this, Director. Within the confines of what you've just discussed, are you confident that the fiscal year (FY) 2022 budget request, which has proposed reductions in the HLS Program, are you confident that that's capable of getting us back to the lunar surface by 2024? And I'll go farther than that to say part of our challenge here in Appropriations, even if we're successful, there's still that little creature called OMB (Office of Management and Budget), and there's still that process of the administration pulling as we push. We need a little more push too over there, but we're pulling on this side. Do you believe the 2022 budget request is enough to do what we need to get done? And, by the way, you can strike out 2024. Give me a number or a date.

Mr. NELSON. Mr. Ranking Member, in your State and my State, we have an expression, there are more ways than one to skin a cat. So I've talked directly to OMB about the additional money for us to have the robust competition that we want to have these sustained landings over a dozen years, and that's going to cost some more money. So I've said to them, well, you all are going to consider a jobs bill, an infrastructure bill—and by the way, I haven't even talked about the desperate needs of NASA on dilapidated infrastructure, which is also jobs. And so if you all put together a jobs bill, that's another way of funding. Otherwise, you look at the request, and that's your question, is the President's request. It is a very robust NASA request. It's over a 6 percent increase, and look at what's happened in the increases in science and STEM (science, technology, engineering, and mathematics) education, in aeronautics. By the way, we haven't even talked about the first A in NASA, which is aeronautics. Lot of exciting things going there. I'll be happy to answer your questions.

Mr. LUCAS. Along that line, NASA has a very vast portfolio of programs, and it's always challenging to keep all those plates spinning at once. And I'm not sure the general public appreciates you've got deep space exploration, you've got Low Earth Orbit operations, you've got planetary science, astronomy, astrophysics, Earth science, heliophysics, biology, physical sciences, and aeronautics. Among many of those components, how are you going to keep all those plates balanced, Mr. Administrator? Now, I have faith in you. That's a challenge with the dollars you have available.

Mr. NELSON. Well, I agree with you, but I'll tell you, why is NASA consistently thought of by the American public as the most popular government agency, and why does NASA have very little turnover compared to other agencies? It's because the people are so incredibly talented, and because of the mission. They're fairly

happy. And so, obviously, I'm not doing this. It's—they are doing it.

Mr. LUCAS. One last question, Mr. Administrator. In your time in the Senate, you were an incredible champion of the development of the space launch system and the Orion spacecraft, part of a course enabling long term sustained exploration of deep space, and you advocated for using existing hardware facilities, workforces, smooth transition—all very logical. Do you envision NASA using SLS and Orion past the initial Artemis missions?

Mr. NELSON. In reality, yes, because Artemis is the program to go back to the Moon, but that's just—the goal is going to Mars. Because once we get there, we're going to dig down into that regolith, and hopefully in the meantime have a sample return mission. By the way, that's another thing that the Chinese government is trying to do, and is planning to do. And to see what happened to Mars, is there still—in that water, is there any indication that there was life? So the goal is Mars, so the answer specifically on the SLS is it's going to be used as the workhouse, probably in lunar orbit, to then fashion together whatever this new technology that we develop to go to Mars is going to look like, hopefully faster than we can go now, which is 8 to 10 months. By the time you get there, you've got to be on the surface for a year or two, because of the realignment of the planets, in order to get back. If you can sprint there faster, you can stay on the surface weeks, a month, and then sprint back. But all of those technologies we still have to develop. So yes, the answer to your question is the—yes, the SLS will be a workhorse for the future.

Mr. LUCAS. Thank you, Mr. Administrator, and I'd simply note we on this Committee, I think I can say in a bipartisan way, are going to pull as hard as we can. You're our guy in the administration to push as we pull. With that I yield back, Madam Chair.

Chairwoman JOHNSON. Thank you very much. Mr. Beyer is now recognized remotely.

Mr. BEYER. Yes. Thank you, Madam Chair, very much. And Senator, Administrator, I really appreciate your coming. I apologize for the noise. I'm at the back of National Cathedral, awaiting the John Warner service, but I'm really grateful to be moved up a little bit.

Administrator, we're very supportive of the Deep Space Exploration Program as—to Moon as a stepping stone to Mars, and you actually asked—answered my first question already with your promise after the GAO report on August 4 and your new timeline, but I didn't actually ask the question, so let me at least get that out on record, that, with the GAO report on the NASA lunar programs, they noted several, several challenges, that NASA has minimized the requirements for mission success for some programs, that NASA lacks top level Artemis requirements and associated risks, that NASA is relying on key technologies that are still at very immature levels, that NASA hasn't defined management roles and responsibilities, or documented decisions on management practices, that NASA lacks the rigorous systems engineering functions to manage the systems integration across divisions. And then, in addition, the Aerospace Safety Advisory Council has identified concerns regarding systems engineering integration, a lack of clear

roles, responsibilities, accountability, especially for HLS. So are you sure you want this job?

Mr. NELSON. Mr. Chairman, that report was written before some of the changes that had occurred, so parts of that report are dated. And yes, Mr. Chairman, I really am excited about this job, and ready to tackle this challenge. And finally, let me say that John Warner was a special mentor to me. He was our Chairman of the Senate Armed Services Committee, and I grew to love him, and so I'm glad you're there at his funeral at the National Cathedral.

Mr. BEYER. And one more question in the few minutes—seconds I have left, is one of the big concerns will be on space traffic management and orbital debris. It even came up in the President Biden/Putin conversations. We know that NASA has all the data they're measuring, but that you're not a regulatory agency. How do you see NASA fitting into the ultimate solution on space traffic management?

Mr. NELSON. NASA has to be involved because it's our astronauts that are at risk. You put up more junk like China did 14 years ago, when they blew to smithereens a target satellite when they were testing their ASAT (anti-satellite weapons)—you put junk like that, tens of thousands of pieces, then human life is definitely threatened in Low Earth Orbit, which is where our International Space Station is. So, Mr. Chairman, NASA's going to be involved one way or another. As a matter of fact, we're working on technology that will help us get those pieces of debris out, and get them slowed down enough so that gravity will take over, bring them back in through the fiery heat of re-entry that'll burn them up.

We work, of course, with the Space Force, used to be the Air Force, that tracks all of the objects that are about that big or bigger. What I worry about are objects that are smaller. I remember we looked outside the window on our flight, this is 35 years ago, and there was a washer floating right along with us as I looked out the window. If something even that small were to hit at a different angle on a spacesuit in a spacewalk, or even a window of the ISS, it could be catastrophe. So NASA's got to be involved in space debris. Thank you——

Mr. BEYER. Madam—thank you, sir. I yield back, Madam Chair.

Chairwoman JOHNSON. Mr. Posey.

Mr. POSEY. Thank you, Madam Chairman, and thank you for holding this important hearing today about NASA's Fiscal Year 2022 budget proposal. Administrator Nelson, we'll help NASA remain a leader in our Nation's future space endeavors, including our Deep Space Exploration Program that will return American astronauts to the Moon and beyond on American hardware. I'm also delighted that Administrator Nelson appointed NASA Kennedy Space Center's director Bob Cabana to be the new Associate Administrator. And congratulations to you, again, Administrator Nelson, on your unanimous confirmation to your job.

As a former Senator from Florida, you're keenly aware of the importance of NASA centers. In 2010 you were one of the leading champions of using existing shuttle hardware, workforce, and facilities to develop SLS after the cancellation of the shuttle. Your rationale at the time was to prevent an exodus of talent, and smooth

the transition from one system to another. While the Space Coast certainly experienced its share of hardship during that period of time, we've seen significant progress made at the Kennedy Space Center in many areas. Exploration ground systems are preparing for the first launch of SLS, and the Center has adopted a multi-user spaceport approach to accommodate multiple commercial users, which many people never imagined could possibly happen not that long ago. Can you speak to what progress has been made, and what you see for the future at the Kennedy Space Center and our Human Space Flight Program?

Mr. NELSON. Congressman, my home Congressman, representing the Space Coast, and it's a place that I grew up. It's a place that my grandparents, under the *Homestead Act*, in the early part of the last century, actually homesteaded, worked the land, and under the *Homestead Act*, if you worked the land for 4 years continuously, the government would deed you 160 acres. I have a copy of that deed signed by Woodrow Wilson to my grandmother, and that 160 acres today is at the north end of the space shuttle runway at the Kennedy Space Center. So thank you, Congressman, for your representation.

The Kennedy Space Center, and the Cape Canaveral Space Force Station, has unlimited possibilities. The place is throbbing with excitement. All those old abandoned launch pads from the early days of Gemini, and Mercury, and Apollo, and all the various other military missions, abandoned pads, they are coming to life. They are launching new rockets. In addition, it is, as you stated, a multi-use spaceport. And we are seeing the blending of the commercial operations along with the government operations, both military, intelligence, and civilian. And I'll give you as much detail as you want, but it's an exciting future. And that's happening at all the NASA centers and facilities. Take, for example, Wallops Flight Facility in Virginia. Most of the people live in Maryland. It is just exciting, with all of the medium-weight launches that they are doing from there. So there are unlimited possibilities all over the United States.

Mr. POSEY. With the recent achievement of getting a core stage vertical and stacked between the solid rocket boosters and the VAB, has NASA been able to use that as a major milestone to help set a launch date for Artemis?

Mr. NELSON. Artemis is going to go in November. That's the schedule.

Mr. POSEY. OK.

Mr. NELSON. We know that space is hard, and you don't want to do it not in a safe manner, so it's always possible there's going to be delays, but—by the way, Madam Chair, I think you all ought to have a—go down—to come down and see the most powerful rocket ever. This rocket is as tall as the Saturn V, but it puts a punch out of much greater liftoff thrust than anything that's ever launched on Planet Earth.

Mr. POSEY. Thank you for your leadership, Administrator Nelson. Madam Chair, I yield back.

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

Ms. BONAMICI. Thank you so much, Chairwoman Johnson, Ranking Member Lucas. Thank you, Administrator Nelson, for your

leadership. We have the opportunity and the imperative to implement bold, comprehensive, science-based policies to address the climate crisis, and NASA can play an important role in that work. Earth science observations are essential for mapping and monitoring hazards from the climate crisis, including the drought conditions, extreme heat, and wildfires we experience in the Pacific Northwest today.

I'm particularly alarmed with a recent study from NASA and NOAA (National Oceanic and Atmospheric Administration) that found that the amount of heat the Earth traps has roughly doubled since 2005. So, as co-Chair of the House Oceans Caucus, I know that without bold action to address the climate crisis, the ocean will continue to take the heat for us, and the warming temperatures, as you know, Administrator Nelson, are resulting in more frequent weather—extreme weather events, ocean acidification, and the loss of biodiversity. So during your time in—your tenure in the Senate, I'm grateful for your work to expand scientific research, monitoring, and adaptation measures for harmful algal blooms, HABs, and hypoxia. We've seen this issue in the warm "Blob" off the Pacific Coast, in Lake Okeechobee in Florida, and lakes and rivers across the country. We need more accurate information to help predict and mitigate HABs, so how can the PACE (Plankton, Aerosol, Cloud, ocean Ecosystem) mission help accelerate our understanding of harmful algal blooms, and how can these observations contribute to the goals to the U.N. Decade of Ocean Science for Sustainable Development?

Mr. NELSON. May I give you some additional information in addition to answering PACE?

Ms. BONAMICI. Yes, of course. I do have another question, so I want to leave time for that. Thank you, Administrator.

Mr. NELSON. You want to ask your next question? I'll——

Ms. BONAMICI. No, I'll wait until your——

Mr. NELSON. OK.

Ms. BONAMICI [continuing]. First one——

Mr. NELSON. First of all, you cannot mitigate what's happening to the climate unless you can measure it——

Ms. BONAMICI. Correct.

Mr. NELSON [continuing]. And we are uniquely situated—a lot of people don't know that NASA—all of that—those assets up there, NASA designs them, builds them, launches them, and NOAA operates them. And, of course, look at the accuracy of weather predictions now, and it's going to get a lot better, because not only are we relying on the Earth sensing spacecraft that are up there now, over the next 10 years we're putting up five great observatories. It's a $2–1/2 billion project over a decade. They're going to measure anything that is happening with the land, the water, the ice, and the atmosphere, and they're going to put together a 3D composite of all this information, interrelated with all the other assets we have up there, to help us fine tune our understanding of what is happening to our planet.

Ms. BONAMICI. Terrific. I look forward to working with you, and Dr. Spinrad at NOAA, on that important issue. Thank you, Administrator Nelson. And I know NASA recognizes the need to invest in our next generation, and also the importance of a diverse work-

force, so this budget would strengthen the Office of STEM Engagement, after the previous administration tried multiple times to terminate the program. I'm the co-founder of the STEAM (science, technology, engineering, arts, and mathematics) Caucus, and also a fan of Cady Coleman, the astronaut who played a flute duet from the International Space Station, so I want to recognize NASA for the recent partnership with LEGO Education to distribute STEAM curriculum, because integrating the arts into STEM curriculum has shown to improve academic outcomes, and engagement, and boost creativity. I urge the Office of STEAM—STEM Engagement to continue developing similar initiatives, and I want to ask how—if you could please talk about how that Office of STEM Engagement will foster a future innovative workforce, and also improve diversity at NASA?

Mr. NELSON. Thank you to the Congress that, when it was zeroed out in previous budgets, you all always restored the education for science, technology, engineering, and mathematics. What is happening is this particular proposed budget has a very robust increase in that. Every one of your congressional districts has a university, or a community college, that has got some STEM grants for students. It's especially—now, NASA's not the only agency that does that, but NASA is unique in our STEM projects because what gets kids excited about those subjects? Space flight. And so we are uniquely positioned, and that's why we utilize our astronauts so much not just to fly in space, and do all of the critical stuff, but to go out to colleges, universities, and high schools to talk to kids, to get them excited. And so we are really—between Pam, and Bob, and me, we are really going to push STEM education. And I think you'll be pleased. And again, thank you for restoring it every time it got zeroed out in the past.

Ms. BONAMICI. Thank you, Administrator. My time has expired. I yield back. Thank you, Madam Chair.

Chairwoman JOHNSON. Thank you very much. That was good news to hear. Mr. Babin?

Mr. BABIN. Yes, ma'am. Thank you, Madam Chair, and thank you, Senator Administrator Nelson. Appreciate you being here. President Biden's first budget—you've already addressed some of this, but I'd just kind of like to get it on the record. His first budget request is 445 million lower than the Trump Administration's last budget request, 2.39 billion below what the Trump Administration proposed for fiscal year 2022, and 7.757 billion below the fiscal year 2022 to 2025 budget proposed by the Trump Administration.

The proposed cuts from exploration are very staggering. While the Biden Administration expressed support for continuing the Artemis Program to return U.S. astronauts to the Moon by 2024, this year's request cuts 14.5 billion over the next 4 years from the Exploration, Research, and Development Account that would fund the human landing system and necessary lunar surface capabilities. Specifically, the budget request cuts 3.193 billion from the HLS budget proposed by President Trump for fiscal year 2022, and a total of 10.05 billion from the Trump Administration's fiscal year 2021 request for HLS for the fiscal year 2022–2025. Now, I know what you said about the old saying, and we have that same old saying in Texas too. There's more than one way you can skin a cat,

but just for the record, are you saying there will be no cuts of any programs in the program itself for Artemis because of these cuts?

Mr. NELSON. If we are the beneficiary of your generosity, there definitely won't be. Remember what I said a few minutes ago, it was a $3.4 billion request for human space flight for the exploration part. The Congress appropriated 850 million. And so you can only get so many pounds of potatoes out of a 5 pound sack.

Mr. BABIN. Amen, yeah.

Mr. NELSON. And if you all are generous, whatever vehicle you use, and—including the jobs bill, as an alternative, then we're going to try to rev it up, Mr.——

Mr. BABIN. All right.

Mr. NELSON. —Mr. Ranking Member.

Mr. BABIN. All right, sir. Thank you. In the late 1990's Congress passed the *Commercial Space Act of 1992*. This was before my time here on the Committee, and a little after your time. The law contained a provision called anchor tenancy, that allowed NASA to enter into multi-year contracts for the purchase of a good or a service if the administrator determines that the good or service meets the agency mission requirements, the commercially procured good or service is cost-effective, the good or service is procured through a competitive process, existing or potential customers for the good or service, other than the United States Government, have been specifically identified, the long-term viability of the venture is not dependent upon a continued government market, or other non-reimbursable government support, and private capital is at risk in the venture. Has NASA specifically identified other customers for our human landers or spacesuits that would make these commercial ventures viable without NASA funding?

Mr. NELSON. We always value competition, because you get the best product the most efficient way at the least cost. All those other procurement things that you just talked about, I don't know about those, but I'll find out.

Mr. BABIN. OK.

Mr. NELSON. But I know what I just said is the goal.

Mr. BABIN. Yes, sir. OK, No. 3, I think I've still got time. I proudly represent the Johnson Space Center in Houston, home to Mission Control, the ISS Program, and Astromaterials Acquisition and Curation Facility, and where the world's leading experts in spacesuits reside. You served as the Chairman of the Space Subcommittee here in the House, and represented the Kennedy Space Center in the Senate, so I am assured that you understand how centers play a unique role in your space enterprise. Can you give us assurance that NASA will not attempt to relocate, outsource, or degrade any of these world-class, irreplaceable capabilities?

Mr. NELSON. Remember, I looked at my role in the Senate was I not only represented the Kennedy Space Center, I had to represent all of NASA, and indeed have spent a good bit of time training at the Johnson Space Center. And yes, I can give you some information that'll reduce your heartburn. And, indeed, the spacesuit program is intended to stay at Johnson.

Mr. BABIN. Sounds good to me, Mr. Administrator. Thank you very much, and I yield back, Madam Chair.

Chairwoman JOHNSON. Thank you very much. Ms. Stevens is recognized.

Ms. STEVENS. Thank you, Madam Chair, and thank you, Mr. Administrator, for your just very lovely oral testimony. I also very much enjoyed your written testimony. And just for the record here, I want to quote the quote that you provided, which was, in your conversation with our President on a phone call to NASA Jet Propulsion Laboratory (JPL), the President said, "We can land a rover on Mars, we can beat a pandemic, and with science, hope, and vision, there's not a damn thing we can't do as a country." And here we sit, back in this room, with our Proverbs quote, "Where there is no vision, the people will perish." And so, Mr. Administrator, we are so grateful and blessed for your tremendous vision of NASA, and your understanding of the assets, and the things that make it go round, and that are going to continue to help our country to lead into the future.

And even before the COVID–19 crisis, Mr. Administrator, a 2020 NASA and Inspector General report stated that the U.S. industrial base is not as robust as it used to be, making it difficult to find qualified technicians and suitable suppliers. Could you tell me how serious of a problem this is for NASA and NASA's supply chain, and if you've thought about coming to Michigan to see our incredible supply chain assets, where we brag not only do we put the world on wheels, we are helping to send men, and eventually a woman, into outer space and the Moon? Thank you.

Mr. NELSON. Ma'am, if you will invite me, I will be there.

Ms. STEVENS. Sounds like a plan.

Mr. NELSON. And I'm looking forward to going to many of your districts, because the strength of our country, indeed, that is reflected in an organization like this is out there, and your specific thing about suppliers, that's a huge strength. Now, we've got to be careful, because some of our supplies we are now dependent on of getting internationally, and some rare metals and materials we are finding are in other countries that may not be necessarily friendly to us. That's a supply chain not only for NASA, for the whole of government. But—let me just put it this way. If you think back, when we were challenged before, and the Soviets took the high ground, and they shocked us out of our wits with Sputnik, and then with Gagarin first in orbit, and they even got Titov in before—and we could only get Alan Shepard and Gus Grissom into sub-orbit. And then that all changed with John Glenn, who knew that he had a 20 percent chance of failure on that Atlas ICBM (intercontinental ballistic missile), and it worked. And then the Nation said, we've got a goal, evoked by a very young and inspirational President, and we did it. And what happened to the country was extraordinary, because—we talk about STEM education, for generations the excitement of achieving that goal not only rippled through our society in spinoffs, but also in science, and technology, and engineering, and mathematics that led to the technological revolution that we are now beneficiaries of.

Ms. STEVENS. Yeah.

Mr. NELSON. I suspect that what's going to happen, if we can get people really excited about us going back to the Moon, and on to

Mars, that we're going to see a similar kindling of that excitement that will produce an educational revolution again.

Ms. STEVENS. Sure. And we're certainly already seeing that diversification in a place where I call home, where the companies that produce the tubes that went into the auto engines are now producing the tubes that go into our rocket ships, so—I gave him extra time to answer because I like listening to the Administrator talk so much, but I will get back to you on questions for the record, and yield back the remainder of my time. Thanks, Madam Chair.

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

Mr. GONZALEZ. Thank you, Madam Chair, Ranking Member, and the Honorable Mr. Nelson, for being here. And I do want to thank the Chair and Ranking Member for showing an example of how Committees should operate. It's always a pleasure to be on this Committee because we actually work together quite productively, so I appreciate their leadership.

Administrator Nelson, I have the pleasure of representing Northeast Ohio, and the Glenn Research Center is just outside my district. I hope to host you there someday. And, as you know, they've been working hard on the power and propulsion element for Gateway with their technology, and development in solar electric propulsion, which will be demonstrated on Gateway, and will be critical for future Moon and Mars missions. Gateway is also a key catalyst for bringing our international partners to the Moon, much as the ISS has done for Low Earth Orbit. With the recent announcement from China and Russia on their active efforts to court international partners for their lunar research station, I believe Gateway is more important than ever. Can you please discuss the budget request for Gateway, and how this request will keep Gateway on schedule to remain a key part of Artemis, and how NASA will continue to partner with both industry and our international allies on Gateway?

Mr. NELSON. The budget request for Gateway is pretty good, and why Gateway? Because when you put, in effect, a small space station in lunar orbit, then you can do a whole bunch of things in our preparation to go to Mars. No. 1, it becomes a way station for us to go down to the Moon and do all the things that we're doing down there, and all of that is necessary in the preparation of making us able to sustain human life to go all the way to Mars and come back. But on Gateway you can continue research in addition to what, in the future, will be commercial space stations in Low Earth Orbit that will supersede the International Space Station, which I hope will go on until 2030, and I request that of you, that you extend the life of the ISS to 2030. But Gateway will have additional research related to further deep space.

But then what it does also, it allows us to prepare to go to Mars, because it is quite likely that we would then, outside of the lunar space station, be the area where we would put together the components of whatever is the new technology that would take us as a spacecraft all the way to Mars, and land with humans, and return. So it's going to have a number of functions, and it's important.

Mr. GONZALEZ. Excellent. I want to shift toward auditing and China investments. I know this is a big priority, of yours as you've shared repeatedly, your concern about the rapid development of the

Chinese space program, and the challenges this will present to U.S. leadership. Some of this includes China's efforts to work around our laws and leverage their investments into companies to give them additional insight, such as board observer seats into technology being developed in partnership with the U.S. We've seen that across a number of industries, but in particular here. My question is, as we continue to invest more resources into NASA and other R&D agencies, how is NASA ensuring that new startups to the space market who are seeking government investment haven't already received funding from the Chinese government?

Mr. NELSON. Well, I certainly hope that we have the consultations with the Department of Defense and the intelligence community. I have been surprised. I thought I knew a lot about NASA coming in, but what I found out is we are much more involved in understanding the—and participating in the protection of our assets from foreign intrusion than I knew about before, and it is certainly important that we continue that. The threats from abroad now are so multiple, and happening every day, not the least of which are the cyber threats as well, and that is a daily concern.

Mr. GONZALEZ. Yes, sir, and I look forward to continuing this conversation, hopefully, offline. I think we have to do everything we can to make sure that whatever we are funding at the Federal level, whether that's at the universities or at NASA, is not being appropriated and moved over to our foreign competitors. And with that, I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Bowman of New York?

Mr. BOWMAN. Thank you, Madam Chairwoman, and thank you, Administrator Nelson, for your testimony today. As you just discussed with Representative Bonamici, the work that NASA does is so important in capturing the imaginations of our young people. I saw it all the time as an educator, where I spent 20 years of my career before coming to Congress, and I continue to see it in Congress. In fact, I just heard from a rising high school senior in my district named Nathaniel, who talked about how important it is for him—to him that NASA has an adequate R&D budget. He wants to make sure we're staying on track to get to Mars, and asked me to think of the students who may become the next generation of aerospace engineers. Can you tell us a little bit more about your approach to expanding NASA's STEM engagement work? How do we make sure that we're reaching out to students like Nathaniel in every community, including marginalized communities, and nurturing their aspirations?

Mr. NELSON. Yes, sir, Congressman. Right off the bat, the President's budget is a robust increase in STEM, and this particular public servant, joined by Pam and Bob, have this as one of our main drivers because of the value to our country. It's the value to our agency as well. We have a very highly educated agency. We are—in an extension of your question, we are constantly out looking for diversity as well. I want to commend to your attention a good example of that that occurred in the past. As you came out of Mercury, and Gemini, and Apollo, almost all those astronauts were White men test pilots. But coming along with the space shuttle, you didn't need to have test pilots for every astronaut position,

and NASA actually went with a lady who advised them how to go about and recruit women and minorities. Her name is Nichelle Nichols, and she was the actress that played Lieutenant Uhura on "Star Trek." And as a result, the African-American community had a tremendous identification with her. And, as NASA was recruiting astronauts for the space shuttle program, she reached out to the minority institutions, the HBCUs (historically Black colleges and universities), to women, and that first class of space shuttle astronauts, 1978, was suddenly an astronaut class that looked very diverse, especially compared to the previous test pilots. And it was successful. And so we are now extending that. And I can go into the detail on that further, if you'd like.

Mr. BOWMAN. Well, not at this time, but I appreciate you sharing that, and I really want to encourage you to think younger. You know, we have kids who—African-Americans, and Latinos, and people of color dreaming about being astronauts in places in my district like the Bronx, and Mount Vernon, and Yonkers, and if we begin to think of STEM through the lens of—beginning in middle school, from grades six through 12, and putting kids on the pathway beginning at that time, I think that would be tremendous. And please target Title I schools, and the communities that surround them. I think you would get a great diversity there.

I have one quick—last question, Mr. Administrator. Can you speak a little bit about NASA's work with private contractors? We got to the Moon without private contractors, if I'm not mistaken, and now it seems like a lot of things are being contracted out to private institutions like SpaceX. Can you talk about just—so the—the balance there, and reliance on private contractors versus NASA continuing to serve as a public good, if you will?

Mr. NELSON. In the Apollo program, Mr. Congressman, we got to the Moon with American corporations. They did all the work. NASA supervised. NASA had a reason to supervise, because NASA's responsibility is to make sure that it is safe, particularly when you put humans strapped in to all of that explosive potential. And we're just continuing in a different way. Now, why are it—why is it a different way? Well, back in 2010 I had the privilege, in a bipartisan way, with Senator Kay Bailey Hutchison, of—NASA was kind of at a dead still, not knowing where it was going, and we said, we ought to have a NASA program, a government program, but we also ought to have a commercial program, and it ought to be dual track. And that was the NASA bill of 2010 that was passed unanimously in the Senate, and it was passed in the House by a 3/4 vote. And that's the track that we're on. You see that already implemented, that we now have commercial carriers of both cargo and crew to the International Space Station. That has been going on for years now. Now we're going to have a blending of the government and the commercial as we go back to the Moon, and eventually as we continue out into the cosmos.

Mr. BOWMAN. Thank you so much. Madam Chair, I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Waltz?

Mr. WALTZ. Thank you, Madam Chair, and thank you, Administrator for being here today. Over here, sir.

Mr. NELSON. There you are.

Mr. WALTZ. There we go.

Mr. NELSON. There you are.

Mr. WALTZ. All right. I just want to talk to you for a moment about the growing and very concerning Chinese dominance in space. As I'm sure you know, the Chinese Communist Party is openly talking about replacing the United States as a pre-eminent space power. They've launched more rockets and satellites into space last year than the rest of the world combined, including the United States. They just manned its space station, brand spanking new, and openly talking about replacing the International Space Station. 10,000 satellite constellation, are on track, an agreement with Russia to put a research station on the Moon, growing anti-satellite capabilities. Would you agree that we—the United States cannot continue to be No. 1 on Earth if we're No. 2 in space?

Mr. NELSON. First of all, Congressman from Florida, thank you. Thank you for your representation. The United States ought to be pre-eminent in space. We——

Mr. WALTZ. Just in the interest of time, I couldn't agree more. That's what has me scratching my head why we have a half billion cut in the President's proposed NASA budget, a three—75 percent cut to the Human Lander Center—to the Human Landing System, excuse me. Have you spoken with the Vice-President about when her first meeting with the National Space Council will occur? Do you know when that's going to occur?

Mr. NELSON. May I answer your former question——

Mr. WALTZ. Yes, sir.

Mr. NELSON [continuing]. First?

Mr. WALTZ. Absolutely.

Mr. NELSON. We have a 6.4 percent increase in the overall NASA budget, and the cut to which you refer is a result of the Congress making the decision that the request was, for the Artemis Program, $3.4 billion in last year's—in this current year's budget, and you didn't give 3.4. The appropriation was 850 million. So, given the eggs that I'm presented in the basket, I'm trying to get us there, and get us there quick. And so I had said earlier in the hearing that there are more ways to do it. If you're all considering a jobs bill, there's an R&D component of the jobs bill, as well as infrastructure, and it would be very, very helpful if you could consider those increases.

Mr. WALTZ. Absolutely. I think you'll see certainly support from this foxhole. We have to put the first American woman, and the next American man, on the Moon. And to do that, we need a viable landing system, so I certainly think you'll see the support in this Committee. Fight will be ongoing with the appropriators, but I want to see NASA support for that as well.

Mr. NELSON. And yes, Congressman, I have spoken to the Vice-President, and I look forward to her leadership in the council. I'll be meeting with her next week, and I expect that, as the NASA administrator, that I will take a very active role on the National Space Council.

Mr. WALTZ. Mr. Administrator, do you support the Wolf Amendment, which, as you know, prohibits bilateral cooperation with the National Space Council, including NASA, with China, Chinese-owned companies? Do you support sustaining the Wolf Amendment, and if so, making it permanent?

Mr. NELSON. It is the law, and I support it.

Mr. WALTZ. That is fantastic to hear. And, finally, do you support making it permanent, Mr. Administrator?

Mr. NELSON. Yes, sir, and that doesn't mean that we can't find areas of cooperation, and those areas are deconfliction of space assets running into each other, trying to get them to participate in getting rid of all that space junk. That's why I was very—rather abrupt in my comments about when they had the return of a whole big rocket, and it wasn't controlled, and it threatened populations. Now, fortunately, it ended up falling in the Indian Ocean, but it could've fallen in Europe or somewhere in the Middle East, so I have been very harsh in my commentary about the Chinese not doing those kind of things, including the space debris.

Mr. WALTZ. Thank you, Madam Chairwoman. I yield my time.

Chairwoman JOHNSON. Thank you very much. The chair now recognizes our newest Member, Ms. Stansbury

Ms. STANSBURY. Thank you, Madam Chairwoman, and thank you, Ranking Member, and to all my colleagues. It's truly an honor to be here to serve on this Committee with you all. Thank you for allowing me to serve. And I'm especially excited and honored to be able to be here today with our Administrator/Senator, and also I wanted to say, as a former Federal employee, thank you to NASA employees, staff, and researchers for the important work that you do. We so appreciate you. NASA's work is critical, of course, not only to taking us to the far reaches of space, but also for understanding our planet here at home, and particularly our understanding of our planetary systems and climate change, and how that's transforming our communities. And in New Mexico, my home State, that of course is being manifest in terms of chronic drought, extreme fires, and really an uncertain future, and so I am tremendously excited to see the increases for the Earth Sciences Program at NASA in this budget because I think they're extremely important.

But NASA, Madam Chairwoman, is also extremely important as an economic engine for all of our States, and particularly in New Mexico, where we have a very large aerospace industry that is growing daily, and that we are working hard to grow, and is a powerhouse in its own right in aerospace. Also, of course, NASA is a leader in advancing research, and innovation, and American competitiveness in general, and in growing our STEM workforce. And I believe, Madam Chairwoman, that we are at a critical inflection point in our country, in our history, and in our future in restoring science to its proper place in informing our decisionmaking, and growing and diversifying our STEM workforce and our economy, and in deploying science to tackle our biggest challenges, especially in global climate change.

And so, Madam Chair and Mr. Administrator, my question is really focused on NASA's view of our home planet, and particularly the role that NASA plays in climate change. Madam Chair mentioned in her opening that I'm a former employee of OMB, and one of my duties there was actually working on the Landsat program, and one of the significant tensions that we always found with NASA's budget was in balancing the space missions and the Earth-based missions that NASA has. And so, as I said, I was very

pleased to see the increase in Earth sciences. And so, Mr. Administrator, I'd like to hear more about how you see NASA's role in the Earth sciences, and advancing our understanding of climate change, and how that fits into the Biden Administration's overall climate science agenda.

Mr. NELSON. There is a $300 million increase in science in this NASA budget. Earth science is a major part of that. That, in addition to the present unbelievable instruments that we have up in orbit, measuring very precisely what is happening to the Earth's climate. It was just announced that we are going to put up a series of five great observatories over the course of the next decade. The first is a joint one with India that will occur in January of next year. And these five great observatories are all going to collate their information, and talk to each other, in a 3D dimension of what's happening to our Earth by looking at land, water, ice, and the atmosphere. That is going to bring us a new dimension of information in addition to our very precise instruments that are remotely sensing what's happening on the Earth. So the scientific world is quite excited about not only what's happening in planetary science, as we project out, but what we are doing with regard to understanding what is happening here, our own planet.

Ms. STANSBURY. Thank you. And, Madam Chairwoman, and Mr. Administrator, in the interest of time, I would just like to also echo many of the words that we heard today about diversifying our STEM workforce and our aerospace workforce. A recent study issued by this Committee showed that—the ratio of men to women in aerospace, and that NASA is still three to one, and persons of color are still outnumbered three to one in our Federal workforce in this space as well, and I think it's critical that we get more women and people of color serving in our Federal agencies and in the industry. And with that, thank you, Madam Chair, I yield back.

Chairwoman JOHNSON. Thank you very much.

Mr. NELSON. Madam Chair, may I just point out that the next two Senate confirmed positions in NASA, the deputy, Pam Melroy, and the CFO (Chief Financial Officer), Margaret Vo Schaus, are both female.

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

Mr. BAIRD. Thank you, Madam Chair, and good morning to everyone, and thank you, Ranking Member Lucas, as well as Administrator Nelson. We really appreciate you being here and participating in this meeting.

You know, I'm fortunate enough to have Purdue University in my district. It has a strong history of educating astronauts, and producing scientists and engineers that work at NASA, so it is—as you mentioned earlier, it is extremely important that the United States remain a leader in science and innovation, particularly in space. As China and Russia team up and build their space programs, the necessity to remain competitive has also become a point of national security, so I'd like to go to Russia first.

They've indicated that they may withdraw from the International Space Station partnership if sanctions are not lifted against that Nation. You recently had a conversation with Dmitry Rogozin, the Director of the General of Roscosmos and the Russian Space Agency. So my questions are do you merely believe—or do you feel that

Russia will remain in the International Space Station if these sanctions are not lifted? Second question, do you have any idea what the cost to operate the International Space Station might be? And then, in the final years of the Russian Mir Station, efforts were made to privatize the platform. What would prevent Russia from privatizing their segment of the International Space Station?

Mr. NELSON. Congressman, thank you for that question. I want to address it comprehensively. First of all, you said you represent Purdue. Purdue, back in my day, produced almost as many astronauts as did the U.S. Naval Academy, and I wouldn't be surprised if it hadn't surpassed all other universities.

Mr. BAIRD. We appreciate that recognition. Thank you, sir.

Mr. NELSON. I have had three conversations with Dmitry Rogozin last week. I was quite concerned, as you have expressed in your question. Was there—because of these comments that were coming out of Russia, were they going to about-face and break the partnership that we've had with Russia when it was the Soviet Union in 1975, when an American spacecraft and a Soviet spacecraft rendezvoused and docked, and they lived together for 9 days in space. And we've had that cooperation ever since, and it's very evident on the International Space Station because there's always a Russian crew, there's always an American crew on board.

So the first indication was actually in the NBC (National Broadcasting Company) interview of President Putin, when he spoke glowingly about—and that came a day after I had my first conversation with Rogoz, and Putin spoke glowingly about the cooperation in space, particularly on the space station. So, in the second conversation with Rogozin, he confirmed that. And in the third conversation, we had actually participated, I virtually, on a panel—international panel, but they were having the conference in St. Petersburg, Russia. And we had additional information from that conference that confirmed what we were seeing. And then the final thing is they're getting ready, in just a couple of months, to put up a major—another major Russian component to the space station. So why would they be doing that, and just a few years going to abandon it? It didn't make sense. And so I have a much changed attitude about—I think we are going to see the continued cooperation.

However, your question is further. What about Russia and China teaming up? And I think we've got to watch that. I think, as I said in my opening comments, China is very aggressive in its Chinese government space program. And, as a result, we've got to be concerned about that. And if Russia is giving them a lot of their technology on rockets, that's something we've got to be concerned about. And they're talking about going to the south pole of the Moon, and that's where the water is, the water ice. So—indeed. Thank you for raising that, Congressman.

Mr. BAIRD. Thank you for your response, appreciate it very much, and I yield back.

Mr. PERLMUTTER. Thanks, Madam Chair. Mr. Administrator, good to see you.

Mr. NELSON. Yes, sir.

Mr. PERLMUTTER. I don't want you to forget about the University of Colorado that has produced a lot of astronauts as well. I——

Mr. NELSON. Very true.

Mr. PERLMUTTER. So, obviously, you've been involved with a lot more appropriations than I have over the years, but I think the challenge—the competition with China, potentially Russia, offers us some opportunities not to really mix civilian and military, but to find some other pockets that might want to support our space program, and all the phases of it. So, you know, for me, I don't want to see this as a zero sum game, that human exploration takes from Earth science, and Earth science takes from planetary science, and everything takes away from heliophysics. And I do think the fact that there is some serious competition now will give you a lot of opportunities, and I just want to raise my hand. I'd be willing to work with Armed Services, or anybody else, to help you have the budgets that will allow us to be pre-eminent—continue to be pre-eminent in the space program, because—I already gave you one of these bumper stickers, and this Committee, I drive them crazy, because I talk about getting our astronauts, our——

Mr. BABIN. Amen.

Mr. PERLMUTTER. Amen. Getting our astronauts to Mars by 2033, and as you said, the orbital mechanics make that a very good time to do it, saves a lot of travel time. So can you explain to us how you see the Artemis Program helping facilitate us getting to Mars by 2033, or in that timeframe?

Mr. NELSON. Congressman, I don't think the United States wants to be second in anything. And although we were on the surface of the Moon about 52 years ago, we said we're going back, and it is part of a greater mission to go further, and that's to Mars. But mindful that we are seeing competitors that are being very aggressive. That, I think, is going to create the juices flowing, and I believe competition is always good. And that means we better be trained, and disciplined, and ready.

Mr. PERLMUTTER. So you've mentioned, and I think you've answered in a couple questions, having NASA, in effect, participate in the infrastructure bill, that it be part of the jobs plan, or something. How do you see—and I agree with you, by the way. How do you see NASA fitting into, say, an infrastructure plan?

Mr. NELSON. NASA, at a minimum, has $5.4 billion of desperate infrastructure needs. The building down at Michoud, which is a part of the Marshall Space Flight Center, but this, located in New Orleans, that's where we're assembling the first stage of the SLS rocket. The building has holes in the roof, and so it's emblematic of infrastructure that has—and it's not just NASA, it's everything. Look at the roads and the bridges. NASA has a need for that. And if you all do a jobs bill, I hope you would consider NASA in that jobs bill.

Mr. PERLMUTTER. And I think you're going to find this Committee, despite them—you know, me making them all crazy with some of the things I have to say, we work very well together, and I think you're going to get a lot of support from us, both sides of the aisle, in—whether it's an infrastructure issue, or, you know, putting the building blocks into place to get to Mars. Let me ask you one last question, heliophysics. So we passed a space weather bill signed by President Trump last year. I was a little bit disappointed to see sort of the heliophysics part of the budget reduced

in this year just as we're getting this new legislation in place, and would like to see that plussed up in some fashion or another. Any comment?

Mr. NELSON. But that heliophysics is part of a budget that was increased by 300 million. That's the science part of the budget. And planetary science is a big part of that, and we've got to understand a lot of the stuff on heliophysics, because when we send astronauts back to the Moon, you have a solar explosion, and all that radiation's coming, we've got to have a way to know in advance, well in advance, to save our astronauts so that they don't get fried. Same thing on the long trip to Mars. We've got to be able to understand what's coming. And, on Earth climate science, we need to better understand the effects of the Sun with regard to delicate measurements of our climate in order to be better stewards of our planet.

Mr. PERLMUTTER. Thank you, Mr. Administrator. Thanks, Madam Chair. I yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Sessions?

Mr. SESSIONS. Chairwoman, thank you very much. Administrator, thank you for taking time to be with this important Committee. I want to thank the leadership of this Committee, not only the gentlewoman from Dallas, but also Mr. Lucas, for their leadership.

Sir, there is a big discussion about jobs, a big discussion about need of jobs. Pending the final decision by GAO, is there a document or something that's going to be released from you that will lay out perhaps—I don't know about a visionary statement, but the thinking of NASA about moving forward?

Mr. NELSON. Yes, sir. I don't know that I can pinpoint it to how many jobs it's going to be. We can look into the past of NASA, we can tell you how much money has rippled through the economy as a result of the space program, how much money on a specific part of the space program has rippled through the money, and give you an estimate in the past of the jobs that were created. We——

Mr. SESSIONS. Yes, sir.

Mr. NELSON. We clearly know that that's the case, particularly when you're doing cutting edge technology, and you're developing new things, and suddenly you've got a whole new line of employment. And that's going to occur as we develop the technology to go to the Moon and Mars.

Mr. SESSIONS. Yes, sir. Let me move away from perhaps the word "jobs," and go to the word "document." Is there a document that you're waiting to produce to release that, in essence, I think would provide some specificity toward NASA's thinking about what they're talking about of not just competition, but actually what would be on the Moon, how they might move forward? Is there a document which you're preparing that would be available soon after the GAO decision?

Mr. NELSON. We'll prepare that document once we know what the path is forward as a result of the GAO decision.

Mr. SESSIONS. OK. And that's where it then comes to the word jobs. You and I both know we have Blue Origin, we have Boeing, we have Lockheed-Martin, we have, back in the district that I represent in Central Texas, McGregor, Texas, SpaceX. There are a lot

of people in this area. I would say to you that I find intriguing, and really essential, the thinking of this administration, through your service, sir, about what that future looks like, because I think that the development of jobs has a lot to do with the ability that a company has to know not just of the funding, but of the strength of these mission to have long term employment, to have long term decisions about what kind of people they have employed.

I spent a few years at an old organization that changed names a number of times, but essentially it was Bell Labs. And Bell Labs needed to know about where they were headed to to where they could make longer term decisions, and I would say to you that I think that your mark on that vision statement about what would be competition, where we're going to land, whether we're going to put a space station up, whether we're going to put something on the surface, and playing that out, I think you've indicated you've got a pretty good handle on that. NASA has an idea about where they want to go, and the specificity of that, when available, will enable these companies, like SpaceX and others, to then make a determination about where they're going to head not just with jobs, but how they're going to recruit, how they're going to retain. And, as you know, there's a very aggressive schedule of flights, and moving forward, and I think that is part of the vision statement.

It's a joint exercise that you're doing, public/private partnership, so to speak, but with the vision of NASA, so I really want to thank you. I remember back to Dan Golden very well, and Mary Ellen Weber, who was one of his favorite astronauts. Jim Bridenstine I think did a great job, as Dan Golden did, and I think you stand at that doorway of being able to give a great vision and statement, but I would say back to you, these companies that have these leading edge scientists need that viewpoint, and so last question, what do you think about timeframes of that release?

Mr. NELSON. Shortly after the GAO decision. And, Congressman, further, I would say that the past is prologue. Look what happened to the jobs in this country in the field of STEM as a result of the Apollo Program, where a major goal was set, and the Nation decided collectively, the whole of government, the whole of American free enterprise, that we were going to accomplish that goal, and look at the jobs that came out of that that then revolutionized that. Look at the microtechnology that came when you had to develop small in size, low in weight, and highly reliable instruments for the Apollo Program, and look what that did. Everything from watches to computers, and we're seeing that today, and we'll see more of that as we get on down the road on—going back to the Moon, and on to Mars, as well as all these other things in science that we've been talking about.

Mr. SESSIONS. Administrator, thank you. Everyone else has had a chance to put in a plug. I too would like to have you come to Waco, Texas, and visit McGregor, Texas, where SpaceX is. I think you'll be, once again, reinvigorated by the free enterprise system of bright people, and I want to thank you for your service, not just in the U.S. House and the Senate, but also your service now, and good luck, and Godspeed. I think we will salute to a great plan, and thank you. I yield back my time, Madam Chairman.

Chairwoman JOHNSON. Thank you very much. His invitation to Waco will only follow one to Dallas. Ms. Moore? Mr. Foster?

Mr. FOSTER. Thank you, Madam Chair. Well, first thank you, Ranking Member Lucas, Administrator Nelson, for joining us here today. I believe the documents that my Republican colleague Mr. Sessions was requesting are known as the technical design report, and a resource loaded schedule and budget, will—which will be required for the Artemis mission, the Gateway project, and the mission to Mars. When can we in Congress expect a preliminary version of these documents?

Mr. NELSON. After the GAO report.

Mr. FOSTER. So within the year? By the end of the year?

Mr. NELSON. Yes, sir.

Mr. FOSTER. OK. Thank you. You know, you also mentioned in your remarks the importance of developing new technology as part of the realistic ways of getting to Mars. You know, also you mentioned the very difficult problem of radiation shielding, for which, you know, it's—for both the mission to Mars and the Gateway Project, which I believe there aren't really satisfactory solutions yet, a part of which is to make very high performance propulsion systems so you can get to Mars and back quickly.

Now, the National Academies recently released a report, I think in February of this year, entitled "Space Nuclear Propulsion for Human Mars Exploration", which looks at a lot of the technical details for really, you know, getting a higher performance mission to Mars—propulsion system for the mission to Mars, and it recommended that if you're—in order to support human missions to Mars as soon as—well, they were planning on the late 2030's, that NASA needed to invest money now in a very aggressive technology development program for the propulsion that addresses the fundamental challenges both for thermal nuclear and electric nuclear propulsion. Congress has maintained an interest in space nuclear power and propulsion through both the authorization and appropriation language, including $110 million in the FY 2021 appropriation. Could you comment on why NASA's FY 2022 budget does not propose any funding for either nuclear electric propulsion or nuclear thermal propulsion technology development and demonstration activities?

Mr. NELSON. Congressman, it's going to have to in the near future, because the alternative is to go to Mars with conventional technology, which is going to take us 8 to 10 months to get there, and then you're going to have to be on the surface for 2 years before you would bring the crew back for another 8 to 10 months, and that's because of the alignment of the planets, so that you could get back in that short a period of time. So is it realistic that you could send a crew all the way to Mars and sustain them on that distance of millions and millions of miles? I think—my personal opinion is—now, I am not a scientist, so we're going to have to listen to the propulsion folks, but my country boy understanding of this is that we are going to have to speed up one way or another, try at least to get it down to a year on the surface.

Mr. FOSTER. Um-hum.

Mr. NELSON. And you can do that with one of those nuclear—I think it's nuclear thermal.

Mr. FOSTER. Yeah, nuclear thermal. That—my physicist understanding is that it's nuclear thermal, and that the solar options will be mainly useful for getting cargo there with low mass into Low Earth Orbit. But I'm really—you know, I would've expected a more aggressive budget proposal if that's going to be a serious option. You know, one of the very positive things that's happened is that there seems to be a convergence on the use of low enriched uranium for these missions, because there had been previous discussion both for surface power reactors and propulsion reactors using ion enriched uranium. This is, to my mind, a very dangerous future, where multiple countries will have large amounts of weapons-usable uranium as part of their propulsion reactors because of the ease at which they could be converted to nuclear weapons, and the world, and space, will be much safer if we standardize on that. It's been a real step forward, I think for the world that we're focusing on the low enriched uranium designs for both the surface and the propulsion reactors. But I urge you to really, you know, give that program a healthy kick, because it's going to be essential to get the performance we need for a Mars mission on the schedule we hope to see it happen.

Mr. NELSON. Congressman, you obviously are skilled in this very technical area, and I might say, I think you're correct that we're not going to be handling a lot of highly enriched uranium, because it's very important in another part of our government that that doesn't get out of our control, and into somebody's hands who can use it to build a bomb.

Mr. FOSTER. No. Absolutely. And the advanced nuclear reactor concepts for—that are looked—being looked at for commercialization are also moving toward high enriched—well, low enriched, high assay material, which is much safer. And so I think the convergence of NASA and the commercial reactor world is a very positive trend that we should encourage. My time is up——

Mr. NELSON. And nuclear electric, Congressman, offers new possibilities. We're just not there yet. You could develop a rocket, like one that's being experimented on VASIMR (Variable Specific Impulse Magnetoplasma Rocket), it'd get us there in 39 days. It'd go—accelerate halfway, and decelerate the remaining half. Once you're there in 39 days, the planets don't get out of alignment, and you can stay a week or two, a month, and you can sprint back 39 days. But the technologies are not there. These are the things that we're going to have to develop before we end up with the technology we're going with in the 2030's to Mars with humans.

Mr. FOSTER. Thank you. And I'm over time, and I'll yield back.

Chairwoman JOHNSON. Thank you very much. Mr. Garcia?

Mr. GARCIA. Thank you, Madam Chair, and Ranking Member Lucas, for both of your leadership and partnership on this. Administrator, it's good to see you again, sir.

Mr. NELSON. Thank you.

Mr. GARCIA. When we last spoke—well, first of all, let me commend the achievements from last year. I mean, to be able to send the Mars missions up, launch Americans from American soil, in American-made hardware, and to have SpaceX recover safely 26 flights in 1 year, which is about three times what the space shuttle was able to do in 1 year during its best years, is a massive achieve-

ment in any year, but especially during a pandemic. I think we have proven out the government and commercial partnership aspects, and the model works. I think we need to figure out how to continue to accelerate that, incentivize industry, keep industry interested in these programs, and not grind them to a halt on contracting issues. To that point, you know, I hope that is something that NASA's looking at, is how do we get folks on contract quicker, how do we maintain the fixed price incentive fee contracting, rather than cost-plus incentive fee type contracts. There's a lot of ways to skin a cat, but, as you know, there's a lot of ways to kill programs, and these are the barriers to entry that we sometimes see on the defense side.

I want to just put a bow real quick on the HLS conversation. There's been a lot of discussion. The problem that we have with the August 4 decision is that, between now and then, we're actually going through markups within the Appropriations Committee that I sit on as well, so I just want to put a bow on the acquisition strategy. You mentioned in the Approps conversations a couple weeks ago that this first HLS award was effectively a one-off demonstrator for the first mission. You used the word demonstrator again today. The inference of that would be that there are follow-on competitions, and that represents, effectively, your acquisition strategy, but that's not reflected either in the fiscal year 2022 budget request, nor the 5 year plan. And so, just to make sure we're all on the same page—because there really is only two scenarios coming out of August 4, either the protest is upheld or it's not. If it's upheld, we still have a massive funding gap, to the tune of 5.4 billion. That—your plan is to use the *JOBS Act* to get healthy enough, either directly or indirectly through other programs, to pay for the follow-on HLS programs?

Mr. NELSON. Well, that's up to you. That's up to you, if you decide to appropriate the money in order to have these follow-on competitions, and many landings, one a year over a decade. And, by the way, they will be fixed price.

Mr. GARCIA. Good. OK.

Mr. NELSON. Fixed price contracts.

Mr. GARCIA. Good. I just want to make sure that that ask is on the table, and that, not only the authorizers, but the appropriators are aware that that is the plan to get whole on this overarching acquisition strategy, and if that's the case, that we need to codify that as we move through the next couple of weeks before August 4.

I resonate with the—competition is good. We need to keep pushing in that direction, and I think NASA's doing a good job of that. More horses in the race is always good. I want to dive down into a couple specific programs as well, if you don't mind, Administrator? The Mars Sample Recovery, you mentioned early on that that was still something we were chasing. We have the rover now on the planet. We have it collecting samples here, but we don't have necessarily the program of record or the funding to bring back the samples. That could be a large bill. Where is that captured in the strategic plan or in the budget request?

Mr. NELSON. It's being designed right now——

Mr. GARCIA. OK.

Mr. NELSON [continuing]. And as soon as we have—I've seen one concept. It's a very complicated concept. They want to make sure that the material is not contaminated once it comes back. All of this is done in a very elaborate instrument that they land on——

Mr. GARCIA. Um-hum.

Mr. NELSON. —Mars——

Mr. GARCIA. Um-hum.

Mr. NELSON [continuing]. Taking the sample that will be collected by this rover, Perseverance, transferring it to the other, preparing it, and then putting it, in effect, in a capsule that then launches from the surface of Mars, and comes back, and then comes back through, with a heat shield, through the entry of the atmosphere.

Mr. GARCIA. OK. So we're still characterizing the price footprint of that design, and——

Mr. NELSON. Yes, sir.

Mr. GARCIA [continuing]. It's going through design reviews? OK.

Mr. NELSON. Yes, sir.

Mr. GARCIA. Last, in the remaining 10 seconds, we have a program in my district called SOFIA. This is a 747-based infrared instrument, just upgraded with a new instrumentation system recently, partnership with Germany, lots of money being spent on that, that's set to be terminated within this budget request. I would request that you look at that, at least wait for the senior review in fiscal year 2022 before we make any decisions, and happy to support you in those conversations, and host you in our district for that as well. Thank you, Mr. Administrator.

Mr. NELSON. Thank you, Congressman.

Chairwoman JOHNSON. Thank you very much. Ms. Moore? You're muted.

Ms. MOORE. Thank you so very, very much, Madam Chair, and thank you, Mr. Administrator, for your patience during this very long hearing. Mr. Bowman raised a point, and you didn't get a chance really to respond. You're putting 20 million extra dollars into STEM education, and he proposed that it ought to start like, at K–6, and I'm thinking maybe that's too old. And I just want to know specifically what you're doing to—in the K–12 space in particular in regards to education. I don't think that you give somebody their first slide rule when they're a freshman in college that you're going to do very much in terms of that space.

Mr. NELSON. I understand your concern, Congresswoman. I'm going to try to affect that, because education doesn't start once you enter the university. It starts——

Ms. MOORE. Exactly.

Mr. NELSON [continuing]. A lot earlier. And I think you will see that, in addition to the STEM grants which go to universities, I think you will see us try to expand the efforts of educating kids. We can only do with STEM grants what the law allows, however, we have other ways of getting this word in to even elementary and secondary schools.

Ms. MOORE. That's where they need to be. Mr. Administrator, you have—you've spent a lot of time talking about equity, and gender equity, and what we've noticed on this Committee is that not only were women in low level jobs, like restaurants, suffering

through this pandemic with a loss of job, but we noticed that women published less papers than before the pandemic. And I just want to know if there—can you tell us what the pandemic has done to NASA in—personnel?

Mr. NELSON. Well, fortunately, our personnel were the first to be able, of any government agency, to adapt quickly by remotely being able to work.

Ms. MOORE. Good.

Mr. NELSON. We are governed, on a return to the offices, by the decision of the White House, and we will be governed accordingly. But I can tell you, I'm tired of roaming around in an empty headquarters building basically by myself, now joined with Pam and Bob, so I'm looking forward for everybody getting back.

Ms. MOORE. Absolutely. Mr. Administrator, I just want to point out that I'm from Wisconsin, so this is a long way from Florida. I know how much you admire Florida. But a great example of the partnership with NASA is the partnership that they have—the University of Wisconsin and Boeing partnered under the University Leadership Initiative, and students got to study robotics, advanced aviation manufacturing, which I know you're interested in, and there's a lot of scientific inquiries regarding the Great Lakes system, on the climate of the eastern United States, and even the science behind the formation of tornadoes. Do you anticipate having a bigger footprint in places like Wisconsin during your tenure?

Mr. NELSON. Yes, ma'am, and I've been to Wisconsin. I went there with Tammy Baldwin, not for NASA, but for the U.S. Coast Guard. You've got a station there just south of Milwaukee. And I—if you'll invite me, I'll be happy to come back.

Ms. MOORE. Consider yourself invited. At—because we there—our—there's a great nexus between what we're doing and NASA, so we'd be happy to have you, so consider yourself invited. We'll follow up. And, Madam Chair, I yield back the remainder of my time.

Chairwoman JOHNSON. Thank you very much. Mr. Feenstra?

Mr. FEENSTRA. Thank you, Chairman Johnson, and Ranking Member Lucas. Administrator Nelson, I appreciate you taking the time today to speak to our Committee on NASA and the Administration's Fiscal Year 2022 budget proposal. As you know, China is a significant competitor in space exploration and efforts to militarize space. Last week I introduced an amendment to the *NSF for the Future Act*, along with Congressman Waltz. It was added with bipartisan Committee support during the markup. The amendment related to prohibiting participation in maligned foreign talent recruitment programs, such as China's Thousand Talents Program. The question is, does NASA have an active program in place to assess employees from foreign influence, or prohibit their participation in maligned foreign talent recruitment programs?

Mr. NELSON. If we don't, we will.

Mr. FEENSTRA. That's good. It's so important. I think it's critical to our country that we focus on those around the communist world that have concerns about our country. Another question I have, moving on to the issue of agriculture, the future of sustainable aviation fuel may provide a new market for biofuels produced in Iowa. Looking at your budget, how does biofuels play out in sus-

tainable aviation fuel, and related research and development, in your budget for fiscal year 2022?

Mr. NELSON. The first A in NASA is aeronautics, and we're looking at all kinds of fuels. Basically, NASA aviation has got to do our part in lessening the pollution of putting CO_2 and methane up into the upper atmosphere. So we are getting ready to fly a demonstrator on an all-electric aircraft coming up this year, and that's just one trying to look at alternative fuels. Now, how the biofuels work into this, I can't tell you off the top of my head. I know before we've seen biofuels into the American automobile industry, because most of us are at least getting 10 percent ethanol when we pump at the gas pump. I know the Air Force in the past had had a program that was going to be directed at mostly biofuels. When you launch rockets, you've generally got to have something that's really got a kick, and usually that's something like kerosene, or hydrogen, or methane. So—but getting back to aeronautics, we are doing that, and doing it aggressively.

Mr. FEENSTRA. That's great to hear. Relating to agriculture, NASA's applied sciences and NASA's Harvest Program work to advance the use of satellite observations to benefit agriculture and food security. Can you talk about NASA's budgeting to develop applications to assist precision agriculture, and provide data in support of agriculture and land use issues, such as drought forecasting, or flood plain mapping control?

Mr. NELSON. So—I'm an old country boy, so—as a matter of fact, I can even remember my grandfather plowing a mule, but think about today. The farmer gets in an air-conditioned tractor, and he's got a GPS (Global Positioning System) system, and it's telling him exactly how to furrow that row. Now, what about all the scientific instruments that we have now that can examine the crops from space and see what's diseased, or what about the ones that are going to be able to predict drought in the future to help the farmer? Or what about the desert community that suddenly, under the soil of the desert, we can locate deposits of water? All of those things are bound to be helping agriculture and country folks. And I think it's exciting.

Mr. FEENSTRA. I do too, and, Administrator Nelson, I greatly appreciate listening to you today. It's an honor and a privilege for a farm kid in Iowa to listen to you. And, with that, I yield back. Thank you.

Chairwoman JOHNSON. Thank you very much. Mr. LaTurner?

Mr. LATURNER. Thank you, Chairwoman Johnson, and Ranking Member Lucas. Administrator Nelson, it's a pleasure to get to interact with you today. Of your many accomplishments, my favorite is that you're a fellow former State Treasurer, so it's great to see you here today.

Now that the Commercial Crew Program is fully underway, NASA will have the ability to add additional crew members to the ISS, how will NASA and international partners' crew time be impacted by the private astronaut mission?

Mr. NELSON. Well, I think that's a concern, and I think we constantly have to monitor that. And what I have suggested, as a newbie, but one who is responsible, is that they have the same training that our professional astronauts have, they go through the

same medical checks, the same kind of psychological checks, and that you have an experienced astronaut with them. Thus you see that the company that's going to do the first private astronauts to the space station has Michael Lopez-Alegria, one of our very experienced astronauts, that is conducting the training. They're even going out in the desert for, like, a week in order to create the bonding of a crew. And they have also named Peggy Whitson, who has spent more time in space than anybody else, at some 800 plus days, is going to be the astronaut that will accompany the second group that's much further on out. So you raise a very valid concern, and I have been trying to address that.

Mr. LATURNER. I appreciate that. NASA continues to propose transferring specific space communication efforts over to the private sector. What progress has NASA made on this front?

Mr. NELSON. On which front?

Mr. LATURNER. On transferring specific space communication efforts over to the private sector. I'm curious about the progress you made, and also the response that you've received from the private sector.

Mr. NELSON. Well, everything that, really, NASA does is the private sector. The private sector that you're referring to is the commercial part of space flight, where we give a request for a proposal, and companies come back and bid, as we have done so successfully, on commercial crew to the space station, as well as commercial cargo. Those are fixed price contracts. But, when it's involving humans, including the docking of cargo missions to the space station, NASA's going to be all over it to make sure that it's meeting the safety standards that we have to have on anything having to do with humans in space. Does that answer your question?

Mr. LATURNER. It does. I appreciate it, and I appreciate your time, and I yield back, Madam Chairwoman.

Chairwoman JOHNSON. Thank you very much. Ms. Ross? Is——

Ms. ROSS. Thank you, Madam Chairman. I hope you can hear me. This is a wonderful hearing, Chairwoman Johnson, and thank you to Administrator Nelson for joining us today. I met you a couple times before, including in my home State of North Carolina, and, as you know, North Carolina has contributed to NASA for decades. Christine Darden, one of NASA's hidden figures, broke barriers in the STEM industry, and in gender and racial equality, and she's from North Carolina. She was the first African-American woman to be promoted into the Senior Executive Service at NASA's Langley Research Center. We also have Christina Koch, a three-time graduate of NC State, in my district, who served as a flight engineer on the International Space Station for three expeditions, and set a record for the longest single spaceflight by a woman, with a total of 328 days in space, and she was a participant in an—in the all-woman spacewalk. And the 62 astronauts, including those on the Apollo 11 mission, trained at the University of North Carolina's Morehead Planetarium.

I believe that inspiring the next generation to reach for the stars well before they earn advanced degrees, and qualify to join NASA, is a crucial, crucial mission both for Congress and for your agency. And in North Carolina, in Research Triangle Park in particular, we're a major STEM education hub, and we've grown our STEM

education at a higher rate than the national average. I'm thrilled to see that, for the first time in many years, NASA's budget request includes funding for its Office of STEM Engagement, and so I'd like to know how the STEM engagement activities are building stronger ties with NASA's mission, including its flight programs.

Mr. NELSON. And Mike Smith, who gave his life for the country in the terrible tragedy of Challenger, was from North Carolina as well, and thank you for the contributions from your State. STEM is—we've had some discussion here already, extensively, about the importance of STEM. You can't be a society that wants to do all of these gee-whiz technological achievements that are giant leaps if you don't have the educated populace. And what better to stimulate the interest of kids in science, and technology, and engineering, and mathematics than the space program? And so we're really going to try to rev up STEM education. It got a big boost in the President's budget, and we're going to try to manage it in a way that it really does have an effect. STEM grants are not the province just of NASA. They're every agency of government. And you will have an opportunity, as you go through these authorization bills and appropriations bills coming on, to affect STEM throughout the whole of government, but we're going to try to do our part.

Ms. ROSS. Well, thank you so, so much. One of the other things that we do well in the Research Triangle is have a very innovative Cleantech Cluster, and advancing clean energy. And can you elaborate on how your agencies work on—research and work on climate change and innovation, can contribute to our domestic clean energy sector, including manufacturing and supply chains?

Mr. NELSON. Yes, ma'am, and we've had considerable discussion on that issue as well. Climate science in NASA is getting a major emphasis. Not only with the very delicate instruments that are on orbit right now measuring all kinds of things, and you have seen the result, for example, in the National Weather Service. Well, NASA's the one that designs those instruments, their satellites, those spacecraft, builds them, and launches them, and NOAA then operates them. But we've got a future that is very exciting. Over the next decade we are going to put up five great observatories, and they are going to give us measurements of what's happening on land, on water, on ice, in the atmosphere in a way that we never had, and then collate all that into a three-dimensional understanding of the subtle changes that are occurring, and what we need to do about that, as well as advise us on a daily basis of what we ought to be looking out for. All of that is around the corner. That's a $2–1/2 billion project over 10 years. Five missions, the first of which will be January of next year. Yes, ma'am.

Ms. ROSS. Well, thank you very much, Mr. Administrator. Thank you, Madam Chair, and I yield back.

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

Mr. GIMENEZ. Thank you, Madam Chair, and Ranking Member Lucas. Senator, Administrator, good to see you again.

Mr. NELSON. Mr. Mayor, good to see you.

Mr. GIMENEZ. Thank you. Senator, Administrator, do you think that China is in a race to the Moon with us?

Mr. NELSON. Yes, sir, Congressman.

Mr. GIMENEZ. Why?

Mr. NELSON. Because of what they've already done, and what they've announced they're going to do. And, by the way, if you look back on the history of the Chinese program, they announce what they're going to do, and then they do it. And so—we've already seen they've been on the Moon successfully. We clearly saw what they've done, as only the second Nation to ever be able to land a rover on Mars. We did so back in the 1970's, and have had several since, but they're the second Nation to be able to pull this off, and it's no minor feat. They are preparing a sample return mission from Mars, so this is demonstrating extreme capability.

They've announced that they're going to send about three missions to the south pole of the Moon. We're sending three commercial probes, overseen by NASA, all looking at water ice, because from that you can get fuel——

Mr. GIMENEZ. Correct.

Mr. NELSON [continuing]. And oxygen.

Mr. GIMENEZ. Right. So—I hate to interrupt you, I only have about 3 minutes. I have a couple other questions for you. Do we know that there's water ice on the south pole?

Mr. NELSON. Yes, sir.

Mr. GIMENEZ. Do we know how much there is on the south pole?

Mr. NELSON. That's why we're going.

Mr. GIMENEZ. OK. And so if you have water ice on the south pole, then you can create fuel, which then you can take off from the Moon a lot more efficiently than taking off from the Earth, and that's why you want to get there. What happens if the United States and China arrive—or somebody's there at the south pole already, and somebody else comes there, who owns, who gets that water ice?

Mr. NELSON. Well, I think you raise a good question, and that's why have something known as the Artemis Accords, which we are getting other nations to sign, Brazil being the most recent. And what the Artemis Accords say is that our exploration of the Moon is going to be transparent, it's going to be peaceful. Nations are going to cooperate together, and there's nobody who's going to be exclusive.

Mr. GIMENEZ. Has China signed that?

Mr. NELSON. No. Neither has Russia.

Mr. GIMENEZ. That's interesting.

Mr. NELSON. It's a data point.

Mr. GIMENEZ. Look, I raise those questions—I knew the answers, but we are in a race with the Chinese to get to the Moon, and it's a matter of national security that we win that race. It's also a matter of national pride that we win that race, just like it was back in the 1960's when we beat the Russians to the Moon. It's a demonstration to the world of who is the pre-eminent power in the world. People don't understand that, but that's exactly what's going on. And so, you know, you'll find in me somebody who will fund, or try to fund, NASA to the greatest extent possible to make sure that we're the first ones back on the Moon.

Related to that, the lander that we just awarded the contract to, when do you expect delivery of the first lander?

Mr. NELSON. Well, that depends on what GAO says on August the 4th.

Mr. GIMENEZ. Well, if they say that there's going to be competition, then there's a $10 billion shortfall in your budget, right?

Mr. NELSON. And that's up to you, then. We'll see, and I've suggested here, before you arrived, that there are more ways to skin a cat than one, and you're going to have a jobs bill in front of you that's got an R&D component, and that would be a good place.

Mr. GIMENEZ. Well, I agree with you that, with all the trillions that are being bannered about, that we should spend some of that on NASA, and assuring that the United States remains, and will always remain, the pre-eminent force in space. You go back in history, it was the countries that were exploring that were always the dominant countries, and so we need to keep on exploring, and we need to be the first, and we need to be the first out there. I know my time is up, and I yield back, but again, thank you for being here, and, again, pleasure seeing you again, sir.

Mr. NELSON. America never wants to give up its DNA as explorers, adventurers, because always we've had a frontier, and we've been successful in capturing that frontier. Now our frontier is up.

Chairwoman JOHNSON. Thank you very much. Mr. Kildee?

Mr. KILDEE. Thank you, Madam Chair, and good morning, or afternoon, I guess, now, Administrator Nelson. Thank you for being here, and let me just say this, thank you for the various forms that your service to this country have taken. It's very much appreciated, and I'm thrilled that you're in the position that you're in right now.

I'd like to talk to you a bit about NASA's Earth Sciences Division, specifically the Earth Applied Sciences Develop program. I understand the program has worked with the Great Lakes and St. Lawrence Cities Initiative for a number of years on projects designed to protect the Great Lakes. I come from Michigan. The Great Lakes are our lifeblood. It literally outlines our boundaries, it defines who we are as a State. The lakes are also critical to our livelihood. According to the Great Lakes Seaway Partnership, shipping on the Great Lakes and St. Lawrence Seaway supported $35 billion in economic activity in 2017.

So, in my time in Congress, I've been working on this. I've introduced and passed legislation that prioritizes and updates Federal mapping of the Great Lakes. We talked—you know, you were just mentioning how we have such an explorer character in our DNA. We continue to need to do more research and exploration even here at home, and the Great Lakes is one area where we can do that. I have asked, in past legislation, to prioritize the mapping of the Great Lakes, introduced resolutions to oppose building nuclear waste repositories in the Great Lakes Basin, introduced legislation to prevent Asian carp from reaching the lakes, continued robust funding for the Great Lakes Restoration Initiative. As you can see, this has been a priority. But the pressure on the Great Lakes as a result of climate change only raises the importance of research and work in preserving what is really an international treasure. So I wonder if you might comment or discuss how the FY 2022 budget would continue the work that your agency is involved in preserving the Great Lakes?

Mr. NELSON. Congressman, I had the privilege of serving with your dad, and it was a great privilege to know him as a colleague. When you have these Earth observations satellites or spacecraft,

they give us all kinds of measurements to address a number of the things that we also address terrestrially here. For example, the invasive species in the Great Lakes, that is just a terrible bane to the existence of marine industry in the Great Lakes, that kind of muscle that clogs up all the drains, that comes in in the ballast water. You know, that's one thing, but what about the algal blooms, or other invasive species, or stormwater runoff, or the coastal flood risk, the wetlands? All of those things we can help the dangerous—the dangers that are facing your constituents by the observations we are making from space. And—then that goes into what I had explained before about these five great observatories that are going to just refine that data, and make it so much more comprehensive. So I'm with you, Congressman.

Mr. KILDEE. I very much appreciate that. I mean, the agency obviously has a lot on its plate, and I will say that I do support your goal of us continuing to lead in this space, literally and figuratively, but to not forget that the agency does have a robust agenda as it relates to life right here on this planet, and I do appreciate your effort, and particularly your continued support for research related to the Great Lakes. It's a critical asset, and it's one that I'm happy to hear that you also appreciate and support. So, with that, thank you again for your service to our country. Madam Chair, I yield back.

Chairwoman JOHNSON. Thank you very much. Ms. Kim?

Mrs. KIM. Thank you, Chairwoman, and Ranking Member. Thank you for holding this hearing. And, Administrator Nelson, welcome. Thank you so much for being with us to discuss the budget request for NASA.

Back in February I had the opportunity to go to JPL to witness the launching and the landing of Perseverance rover, and that was quite an experience, and I was honored to be one of the few Members that were able to do that.

Mr. NELSON. Did you meet Mimi? She is the lady that handled the little helicopter.

Mrs. KIM. I don't think I personally had the opportunity to meet her. But, you know, that was, like, oh, my goodness, it was after 292 million miles and 7 months preparation, right? So it was really, truly, an amazing experience. During that visit what I did was, as soon as I knew I was invited, I reached out to the school districts in my district, and Rowland Unified School District, invited the eighth graders to join me virtually, so I was able to take my laptop, and turn it around, and show the scale model of the rover, and that was quite an experience for the students. And I think that's exactly what we need to do to encourage our young students to take an interest in STEM-related education, and provide the opportunities for them to be encouraged to perhaps dream about being the next engineers, next scientists. And perhaps one of these days they may be the ones taking on that human lander, and go back and retrieve the samples that our astronauts are currently working on to bring back.

And so I'm really excited about that opportunity, and in my view, and I know you share this, we need to keep our students engaged from an early age, and some of my colleagues on both sides before me talked about the importance of providing the educational oppor-

tunities from early on, not when they are ready to go to college, from pre-K to eighth grades. Which is why I'm so excited—and I want to give a plug in for my legislation that I introduced, *Innovations in Informal STEM Learning Act*, and this will create a grant opportunity, and also allow nonprofit organizations to give, you know, STEM related programs before, after, and even out of school programs. So, you know, it's a good plug in for my colleagues, if they're not aware of it, to please sign on and become a co-sponsor of that bill.

So can you please elaborate on how the additional $4 million the budget provides for the next generation STEM project will be utilized? And, obviously, we can talk about the importance of NASA supporting the type of programming that my legislation will call for for our pipeline of scientists, engineers, and astronauts, and so forth.

Mr. NELSON. First of all, thank you, Congresswoman. You have sat here the entire time, so thank you very much. Thank you for your interest. There's a $4 million increase that you——

Mrs. KIM. Um-hum.

Mr. NELSON [continuing]. Talked about, and it is for the emphasis on learning opportunities in K through 12.

Mrs. KIM. Awesome. I think we agree that we need to ensure that today's students have the skills needed to join the STEM workforce, because this is the pathway for job creation, which affects our American economy, and we are going to be ready to boost the Nation's challenges to, I mean to boost the Nation's competitiveness abroad. Thank you so much for that. And I've heard from many small contractors located in my district, which is California's 39th Congressional District, about the importance of space exploration for the region that I represent, so I look forward to working with you, with the Committee, to ensure that our space programs are appropriately funded. With that—obviously we understand. So it's not a question, I look forward to working with you, and I will yield back the balance of my time.

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

Mr. SHERMAN. Thank you. My first question I'm sure has not arisen, in that—because it relates to my district. The Santa Susana Field Lab was used during the Cold War, in the early parts of the Cold War. Various contaminants, chiefly nuclear, remain. The facility—or the acreage is immediately adjacent to the city limits of Los Angeles, surrounded by populated suburbs. Some 451 acres of this is the responsibility of NASA. The adjoining property is subject to the responsibility of the Department of Energy and the Boeing Corporation. So the contamination affects hundreds of thousands of people. There are 700,000 people who have signed a signature demanding a full cleanup of the site. The prior Secretary of the—of Energy, Governor Perry, at my request, made at a Science Committee hearing, visited the site, and yet we still don't have any significant cleanup. A few old structures were removed. I'd like to bring to your attention a documentary, and arrange to get it to you, called "Dark of the Valley", about how hundreds of thousands of people are affected by this contamination. I want to know whether I can count on NASA to work to comply with the consent decree, and actually start cleaning up the facility relatively soon?

Mr. NELSON. Congressman, we take the environment very seriously. As to making a commitment to you, I've got to know the details, and I just simply don't have those. But I can say this, you can tell a lot about a fellow, where he's going, by where he's been, and look at my environmental record over a lifetime of public service, and I think that'll give you some degree of comfort.

Mr. SHERMAN. We will get you fully briefed, and then we will get you a copy of this documentary, which should be available soon. You've noted that the SLS could be used for multiple missions besides sending humans to deep space. Can you discuss your plan to keep a regular cadence for the SLS mission? And you had spoke to my colleagues on the national security of space using SLS, using the Delta IV Heavy, which is being retired. Can you comment on that?

Mr. NELSON. Well, basically, on the Delta IV, you're having the Atlas V and the Delta IV, which have been the mainstay workhorses of getting a lot of commercial, but especially national defense payloads, over time, into orbit, into protection of our country, and those are being replaced as we develop new rockets. And there is a specific timetable. I don't have that on the top of my head.

With regard to the regular cadence of landing on the Moon with Artemis, that is what I hope is going to occur. If we can get a robust competition, and have a decision on what the lander should be, and to have those landings once a year, so thus the cadence that you talk about, have them once a year over about a dozen year period, all of which is for the purpose of getting ready to go to Mars. Learning what we can, the preparation, the systems, the new technology, and dealing in an environment on a surface of a celestial body that is 1/6 the gravity, and we're getting ready to go to a celestial body that's 1/3 the gravity of Earth.

Mr. SHERMAN. Thank you. I hope the Chairwoman will allow me to sneak in one more question. Can you share your perspective on how the Gateway is a critical element of our effort to further explore not only the Moon, but ultimately expand our space exploration to Mars?

Mr. NELSON. I won't go into the detail that I did before to spare the Committee, but——

Mr. SHERMAN. Um-hum.

Mr. NELSON [continuing]. The Gateway, in essence, is a small space station in lunar orbit that will do many things. It'll be a way station for us to go down and back from the lunar surface. It will be a research station. It's international. We've already got a number of partners. And it will be the place that is likely to be the embarkation point where we will assemble a spacecraft, technology to be developed, that will go to Mars.

Mr. SHERMAN. Thank you.

Mr. NELSON. Yes, sir.

Chairwoman JOHNSON. Thank you very much. Mr. Webster?

Mr. WEBSTER. Thank you, Chair. Senator, good to see you.

Mr. NELSON. I think you all have more Florida Members on this Committee than any other State, maybe outpaced by California.

Mr. WEBSTER. We had a big interest. I've been listening—I heard, and it kind of expanded as we went along, all of the amount of information that you're gathering just from being in space, col-

lecting data. And that certainly is useful data. I was wondering how does NASA partner with other government agencies, even local and State agencies, to utilize that from hurricanes in our area, but also there's wildfires, floods, and all kinds of other natural disasters.Just tell me, what's going on right now with that?

Mr. NELSON. The extensive sharing of data among U.S. Government agencies with NASA is just unbelievable. I didn't realize, until I got into this position, how extensive it is. Now, I'll give you a good example. We in Florida, of course, are concerned about the direction and the ferocity of an inbound hurricane. All right. You've got all these assets up there that are measuring all kinds of different items that affect the intensity and the direction of that hurricane. These are all, in large part, assets that are in space. We have the buoys on the ocean that help us, and we have airplanes that fly through and above the hurricane, but we've also got these assets in space that are giving us all kinds of new measurements. And that's just one example on the sharing of data.

Mr. WEBSTER. I was thinking about in Florida we have, speaking of hurricanes, these emergency operation centers all over, and there's police and fire, and everybody has a—a lot of people have a seat at the table, and I'm sure you've been to one before. And they're all moving, and working pieces as let's say hurricane or some other disaster's coming. Are those pieces of information shared there, or can they be, or should they be?

Mr. NELSON. The data of——

Mr. WEBSTER. Yeah, the data that they have—it's in action, it's happening, it's a live storm, and these people are reacting locally to—there's going to be a local flood, or there's going to be a local windstorm problem of some kind. Is that information shared even with those local EOCs (Emergency Operations Centers)?

Mr. NELSON. Yes, sir, and let me give you another example. Some of the spacecraft that we have, for example, will measure the amount of moisture content in the atmosphere, and this is going to be even more evident in these great observatories that we're going to put up. Because measuring what's happening in the atmosphere—now, moisture content of the atmosphere is a major component when we're trying to figure out what that hurricane is going to do in the future, and the direction, and the intensity, and the temperature of that atmosphere, and the temperature of the surface of the ocean, and even the temperature underneath the surface of the ocean. And a lot of that is coming from the very instruments that NASA has designed, built, and launched, and then turned over to NOAA to operate.

Mr. WEBSTER. I could see that. Even the moisture content, when it comes to flooding and other things, because that's also a problem, an aftermath, a lot of times the wind's already gone, the news story's already gone, and then our rivers filled up, and later on, even sometimes a week, 2 weeks, 3 weeks later is the surge of what happens. That's probably pretty awesome—well, I've learned something today. That's a lot more information than I even knew about, so thank you for coming. Congratulations on your new position. I know you do a fantastic job. We really appreciate you coming today. Good to——

Mr. NELSON. Thank you, Congressman.

Mr. WEBSTER [continuing]. See you again.

Mr. NELSON. Thank you.

Chairwoman JOHNSON. Thank you very much. Ms. Bice?

Mrs. BICE. Administrator Nelson, I have good news for you. I think I may be the last questioner of the afternoon.

Mr. NELSON. Well, you have been, ma'am, very, very patient.

Mrs. BICE. Well, thank you for joining us today, and thank you to the Chair and Ranking Member for allowing us the opportunity to speak with you about the budget. First, I hail from the great State of Oklahoma, and there are some great NASA ties, including your predecessor, who was from Oklahoma, as well as General Thomas Stafford, who has a museum in Ranking Member Lucas's district.

Mr. NELSON. Who I saw yesterday, Tom Stafford, a personal friend, who lives in Satellite Beach, Congressman, and I will see Jim Bridenstine for supper tonight.

Mrs. BICE. Well, tell him I said hello.

Mr. NELSON. Yes, ma'am.

Mrs. BICE. First, you mentioned earlier in the hearing that you were concerned about supply chain, and I am honored to be a member of the Supply Chain Task Force, which is looking at the critical infrastructure that has been impacted specifically over the last 18 months because of COVID–19, but also as it relates to the Department of Defense, and what we can do as a country to ensure that we don't have any supply chain disruptions moving forward. And you specifically mentioned rare Earth minerals, and those come from foreign entities, and I think that we have to be mindful, as we look to the future, to figure out how do we prohibit the possibility of not having access to those, which is incredibly important to many of the things that we're doing at NASA, as well as within the Department of Defense. That is something that I know the administration is also focused on, given their 100 day Supply Chain Task Force memo that was put out a couple weeks ago.

In addition, Congressman Waltz made the comment that he's concerned about China, and, as a Member of the House Armed Services Committee, I echo those concerns as well. I think hearing and seeing some of the things that we have seen over the last couple of months particularly, with the landing of a rover on Mars, it's very clear that China is looking to outpace the United States, and it is imperative that we do everything we can to invest in research and development, in exploration, to ensure that that doesn't happen.

In your budget you ask for 101 million for commercial Low Earth Orbit development, and I very much appreciate the collaboration with the private sector and NASA to do that. My concern is how do we prevent another situation like we have seen with HLS? Because currently we are on hold with that particular program until the decision in August comes, and we're on a timeframe here. And so my fear is that we're doing a great job at investing in LEO (low-Earth orbit), partnering with the private sector, but we cannot have delays. It is not in our best interest as a country. How do you prevent that from happening in the future?

Mr. NELSON. Remember, there were delays on the Commercial Crew Program. That was contested as well. As it turns out, it's

been a very successful program. It's a fixed price contract, and the second commercial provider for commercial crew is just getting ready to launch their vehicle at the end of next month, and then a crew on that vehicle at the end of the year. So the law provides that someone can contest an award, and we're not going to be able to avoid that. And we have, indeed, had to go into neutral for the past 100 days because of the big protest, but this is our system. This is the rule of law. And once we get a result, we will move out as quickly as we can.

Mrs. BICE. And thank you for that answer. I appreciate the fact that we do live under the rule of law in this country. The concern I have is that our adversaries don't pay attention to the laws of this country, and they're willing to sacrifice to be able to move forward and advance at a very quick pace, so I think we, as a country, need to be mindful of how we navigate these waters in signing these contracts, and putting these private sector companies—creating these partnerships with NASA so that we're not behind the eight ball. At the end of the day, that's the most important thing, is to ensure the competitiveness of the United States.

Mr. NELSON. Well, remember, you're a big part of this, and all you have to do is look back at Apollo. And—we were way behind, and the American people and the Congress supported a young President's vision of going to the Moon and back successfully within the decade, and it happened. And it was because everybody in the whole of government came together, supported by the American people. So, as we are looking into this adventure that we are all joining in, you are very much a part of that.

Mrs. BICE. Thank you, Mr. Administrator, and, Madam Chair, I yield back.

Chairwoman JOHNSON. Thank you very much, and thank you, Administrator Nelson, for being with us, and spending this time answering all of the questions. The record will remain open for 2 weeks for additional statements from Members, and for any additional questions the Committee may have or ask the witness. The witness is now excused, and the hearing is adjourned.

[Whereupon, at 12:46 p.m., the Committee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by the Honorable Bill Nelson

Questions for the Record to:

Administrator Bill Nelson

Submitted by Chairwoman Johnson

1. **During the hearing, you stated, in response to a question from Representative Bonamici, that "you cannot mitigate what's happening to the climate unless you can measure it" and described NASA's important role in measuring climate change, both with its own assets and by developing satellites for the National Oceanic and Atmospheric Administration (NOAA). With increased funding proposed for NASA's Earth Science program in FY2022, do you see NASA's role continuing to be primarily in the area of space-based climate change measurements or do you see NASA's role changing, expanding, or evolving to addressing climate change, and, if so, how?**

A: With the increased funding proposed for NASA Earth Science in FY 2022, NASA will continue its role in providing space-based Earth system and climate change measurements, conducting research based on those measurements, developing new technologies to improve future measurements, and providing data to inform those working to address and mitigate climate change and its impacts.

NASA's primary role in this area has been, and will continue to be, in making space-based observations of the Earth system, including climate change measurements, to monitor the changes in our globe's physical and biological systems from space. The Agency uses these measurements to advance our understanding of today's Earth systems and processes – the interactions among land, ocean, atmosphere, ice, and human communities – and develop models and estimates of how the climate and environment might evolve in the future.

NASA measurements and models provide information for decision makers – including policy makers – at Federal to local levels. NASA does not make policy recommendations or perform an enforcement function.

NASA will also continue to support our partner agencies, the U.S. Geological Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA), by building their operational space-based observing systems.

2. **NASA's FY 2022 Budget Request proposes a Sustainable Flight Demonstrator as a key component of the Sustainable Flight National Partnership and next X-plane to fly in the late 2020s.**

    a. **What are the overall goals, objectives, and technology questions the Sustainable Flight Demonstrator program is seeking to tackle?**

A: With NASA's FY 2022 budget, NASA Aeronautics is partnering with industry, academia, and other agencies through the Sustainable Flight National Partnership (SFNP) to accomplish the aviation community's aggressive international carbon reduction goals. Through our collective work in three areas – advanced vehicle technologies, efficient airline operations, and sustainable aviation fuels – we aim to reduce carbon emissions from aviation by half by 2050, compared to 2005, and potentially achieve net-zero emissions by 2060.

SFNP is a focused set of major technology demonstrations by NASA Aeronautics and industry, including a first-ever high-power, megawatt-class electrified powertrain for large transport aircraft propulsion, ultra-high efficiency long and slender wings, advanced composite structures produced four to six times faster than the

current state of the art, and advanced small-core engine technologies based on breakthrough NASA innovation.

The iconic centerpiece of SFNP will be a full-scale technology demonstrator X-plane, or Sustainable Flight Demonstrator (SFD), built to test an ultra-efficient aerodynamic design and possibly other new technologies, and retire technical risks, to solve the challenges of integrating those technologies and prove their predicted benefits in flight.

The SFD project is focused on demonstrating critical subsonic transport vehicle technologies in a relevant flight environment. The purpose of the project is to identify and rapidly mature critical technologies that have a high probability of transitioning to the U.S. commercial transport fleet by the early to mid-2030s.

In October of 2020, NASA Aeronautics established a team of seasoned technical subject matter experts, acquisition experts, and project development personnel to lead the FY 2022 start-up of this project. The team is utilizing established Agency processes used by recent supersonic and electric projects to rapidly develop and mature technical, cost, schedule, and risk plans for the SFD.

In December of 2020, in support of the development of the acquisition strategy for the SFD project, the team released a request for information to U.S. industry to help identify technologies that have a high probability of transition to the U.S. commercial transport fleet. A robust and diverse response from U.S. industry airframers and engine companies was obtained. The team found that several U.S. industry responses are aligned with the goals of increased efficiency and reduced community noise for the next generation of subsonic commercial transports. Given the promising responses, in May 2021 the team released a competitive procurement to jump start U.S. industry risk reduction efforts. The team is preparing another competitive procurement action for June 2022 to down-select the SFD demonstrator, aiming at first flight in 2026.

b. How will NASA ensure that technologies tested on the demonstrator will successfully integrate on a single vehicle while also effectively analyzing their individual capabilities?

A: Successful integration of new technologies into a full-scale vehicle and demonstrating them in flight are key elements of this research. NASA will partner with one or more highly capable cost-sharing partners with extensive experience developing, building, and flying large-scale aircraft systems, who will be able to identify and overcome integration challenges. NASA and the partner will leverage model-based systems engineering and analysis tools during development and test phases of the SFD to understand and address integration challenges as well as assess individual technology and system-level benefits.

c. To what extent will the NASA Aeronautics' Sustainable Flight National Partnership integrate incremental innovations that align with industry needs versus more high-risk/high-reward fundamental and applied research technologies with potential large public benefits?

A: The focus of the SFNP is conducting ground and flight demonstrations of advanced technologies in order to reduce the technical risk sufficiently that industry can make decisions about finalizing development of and commercializing the technology. These are high-risk, high-reward technologies that will enable dramatic (instead of incremental) improvement in overall aircraft system performance if incorporated into commercial aircraft. These technologies, resulting from over a decade of collaborative research between NASA and industry, directly align with manufacturers' future needs by enabling them to be commercially competitive and to satisfy airline demand for highly efficient aircraft. This research complements the incremental technology improvements developed and commercialized by manufacturers through their regular product development cycles and incorporated in new iterations of their aircraft.

d. How is NASA balancing innovative research on reducing carbon emissions against research on fuel efficiency that industry may already be undertaking?

A: NASA maintains this balance through extensive coordination with industry and by each party focusing on their respective capabilities and priorities. NASA has been working with industry since 2010 to research and develop technologies required to meet aggressive environmental targets through improved fuel efficiency and other improvements, starting with "N+3" NASA Research Announcements. Drawing on those initial studies, NASA has undertaken a series of research studies and initiated several projects to mature and demonstrate the most promising technologies to raise their technology readiness levels. Some of those activities have been collaborative research in which NASA and industry partners contributed their respective talents and capabilities to joint research efforts, and then validate the resulting technology and concepts through analysis, simulation, and ground and/or flight test. NASA and industry also conduct their own independent research on these topics. Through collaborative research activities and technical exchanges, NASA and industry gain the necessary insights to align their respective efforts and avoid duplicating work.

In the end, NASA innovative research to accelerate technology advancement is beyond the technical and financial risk threshold of industry alone and balances well with industry research portfolios.

3. NASA currently is back to single-string option for crew transportation to the International Space Station: NASA has only one certified commercial crew provider, does not have a contract for seats on the Soyuz, and has not yet finalized an agreement with Russia to fly each nation's crew members on the other nation's crew transport vehicles.

a. What measures is NASA taking to get the second provider certified?

A: NASA is working diligently with Boeing to complete Boeing's certification program. The investigation into the valve issue identified prior to Boeing's Orbital Flight Test-2 (OFT-2) attempt last year is wrapping up and a new date of May 2022 has been established for OFT-2. The schedule for Boeing's Crew Test Flight (CFT) is under review. Data from OFT-2 along with CFT will be used to close Boeing's crew transportation system certification. Final certification will occur after CFT, clearing the way for Boeing to begin Post Certification missions to and from the International Space Station (ISS).

b. What is the contingency plan for the case that SpaceX is unable to provide crew transport to the ISS for any reason prior to the certification of the Boeing Starliner?

A: NASA develops contingency options for specific situations, depending on which vehicle is delayed and which vehicles are available. For the spring 2022 crew rotation, a direct handover between the Crew-3 and Crew-4 Dragon vehicles is planned to ensure U.S. On-orbit Segment crew continuity on the ISS. Additionally, discussions with Roscosmos related to an agreement to fly crew members on our respective crew transport vehicles are proceeding and NASA expects this arrangement to be in place to fly integrated crews by Fall 2022.

c. NASA mandated an organizational safety assessment (OSA) of its commercial crew partners, and one was completed with SpaceX. When will the OSA be completed for Boeing, and will it be comprehensive and comparable to what NASA does for an internal OSA?

A: The Boeing organizational safety assessment (OSA) has been completed and is in review within NASA. Boeing's OSA followed standard NASA OSA processes.

4. The FY2022 Congressional Justification states that "NASA is working to implement a stepwise transition of the ISS from the current model of NASA sponsorship and direct NASA funding to a model where NASA is one of many customers purchasing services…from commercial platforms."

a. When do you plan to transmit an updated ISS Transition Plan to this Committee, as required by the NASA Transition Authorization Act of 2017?

A: NASA plans to submit an updated ISS Transition Plan in early 2022.

b. To what extent will the Plan address:
- **NASA's top R&D priorities while the ISS is still operational;**
- **NASA's requirements for what is needed to support NASA R&D in a non-government LEO module;**
- **NASA's plan for transitioning the NASA ISS workforce off the program once ISS is no longer operational; and**
- **what happens to the ISS Intergovernmental Agreement if NASA shifts to using commercial modules following ISS operations?**

A: The ISS Transition Plan will address all of these topics.

5. What assessments has NASA made to determine the civil servant and contractor workforce needed to effectively carry out a Moon to Mars effort, and what are the results that identify the workforce needs, including an acquisition and contractor workforce to manage future contracts? What, if anything, does NASA need to develop the workforce necessary to carry out a sustainable deep space human exploration program?

A: In order to identify the requirements for civil servant and contractor workforce, NASA identifies its workforce (both Civil Servant and Contractor Workforce) requirements with input from key stakeholders (commercial/international). For current programs and projects, the Agency Commitment process incorporates workforce assessments as part of the overall cost and schedule estimates. For future systems and elements for the Moon-to-Mars effort, life cycle schedules are created, which are used to identify workforce needs and timing, leveraging relevant NASA activities to inform the needs. The President's Budget Request takes into account funding and training needed to ensure the Agency workforce is prepared to carry out a sustainable deep space human exploration program.

6. In testifying before the Space and Aeronautics Subcommittee last month, NASA's Acting Senior Climate Advisor, Dr. Gavin Schmidt, described his current effort "to develop an Agency climate strategy that will provide an integrated approach to the Agency's climate portfolio and will address the Administration's priority for a government-wide approach in response to the climate crisis." What is the status of the Agency climate strategy, and when can this Committee expect to be briefed on its content?

A: NASA began development of its Climate Strategy in May 2021 by convening a group of subject matter experts from across Mission Directorates and staff offices to discuss current climate-related activities. This group has analyzed the Agency's climate portfolio in order to identify recommendations for the Administrator to consider. Further information is available at: https://www.nasa.gov/press-release/nasa-

releases-climate-action-plan, and we would be pleased to brief the Committee.

7. NASA's FY 2022 budget request proposes to increase funding for Space Grant and the Minority University Research and Education Project (MUREP). How is NASA measuring progress and evaluating the impact of the Space Grant program and the MUREP activities?

A: In alignment with the NASA Office of Science, Technology, Engineering, and Mathematics (STEM) Engagement's (or OSTEM's) comprehensive performance assessment and evaluation strategy, Space Grant and Minority University Research and Education Project (MUREP) are both engaged in annual evidence-building activities. Both activities contribute yearly participant demographic data in support of Performance Goal 3.3.3: *Provide opportunities for students, especially those underrepresented in STEM fields, to engage with NASA's aeronautics, space, and science people, content, and facilities in support of a diverse future NASA and aerospace workforce*. This yearly data is compared to the national average of higher education students enrolled in STEM fields.

In addition to performance data, each program has executed annual evaluation activities. In FY 2020, the Diversity Deep Dive study assessed the extent to which Space Grant and NASA Internships broaden participation of underrepresented and underserved groups of students. The study examined historical performance data to understand trends over time and engaged both internal and external stakeholders to assess the extent to which the programs were contributing to the diversity of the future aerospace workforce. Additionally, in FY 2020, Space Grant awarded two cooperative agreements to Space Grant Consortia to conduct two-year, independent Space Grant Program-Level Evaluation pilots. These pilot evaluation studies will be executed in FY 2021 and FY 2022 to determine the impact of Space Grant at the program level, engage multiple consortia, and make recommendations for the scalability and sustainability of program-level evaluation.

In FY 2020, MUREP conducted a Phase 1 Program-Level Evaluation that assessed how and to what degree MUREP is achieving its goals and objectives. The study convened an Expert Review Panel, conducted focus groups, and executed a literature review to develop a findings and recommendations report. In FY 2021, the study will move to Phase 2; Phase 2 will expand upon the Phase 1 findings to examine how MUREP activities are addressing student engagement, partnerships and competitiveness of awardees, and to assess the efficiency and effectiveness of MUREP management and operations to determine new approaches for the future. In FY 2022, the findings of the Phase 1 and 2 evaluations will be used to plan a program-level outcome study.

8. NASA currently has multiple active contract elements for the lunar Human Landing System (HLS) program, including: the Option A Human Landing System award, currently under protest with GAO; the extension of the Human Landing System Base Contracts; and an ongoing solicitation for the NextStep Appendix N, "Sustainable Human Landing System Studies and Risk Reduction," issued in late June 2021, to be followed by a Lunar Exploration and Transportation Services (LETS) solicitation in early 2022.

a. Please explain NASA's acquisition strategy for the HLS program.

A: The overall Human Landing System (HLS) acquisition strategy is to develop, certify, and acquire integrated lunar landing solutions for Artemis using firm-fixed price, milestone-based contracts under Next Space Technologies for Exploration Partnerships (NextSTEP). Base period, Option A and Appendix N are done under a Federal Acquisition Regulation (FAR) Part 35 Research and Development Broad Agency Announcement (BAA). The Lunar Exploration and Transportation Services (LETS) solicitation will be a FAR Part 15 acquisition. A human lunar landing demonstration mission will be performed under the Option A contract. The LETS solicitation will provide regularly recurring human services to and from the lunar

surface. Each of these activities is an integral part of NASA's overall strategy to safely, affordably, and regularly support human lunar exploration.

b. What is the purpose of the HLS baseline award extension?

A: The no-cost extension of the baseline award was an administrative change necessary to preserve the ability to seamlessly transition from the base-period contracts to the Option A contract using the same legal instrument while the Option A contract award protests were being considered by the Government Accountability Office (GAO). The base-period contract scope of work remains unchanged during the no-cost extension.

c. What is the purpose of the sustainable risk reduction awards?

A: The sustainable risk reduction awards, Appendix N, are designed to continue progress on lunar lander designs ahead of the services contract. This Appendix will bridge and support multiple contractors from the time of the Option A award until the time the LETS contract becomes available.

d. What is the purpose of the LETS contract?

A: The purpose of the LETS contract is to procure recurring services to the lunar surface with a built-in design, development, test, and evaluation (DDT&E) effort in advance of the recurring services.

9. NASA is planning to use public-private-partnerships to develop and operate the lunar Human Landing System. I understand that NASA and the contractor are using a blended NASA-contractor team. Under this approach:

a. Who has ultimate decision authority for the Human Landing System development and operation?

A: The contractor proposes their designs, and NASA oversees the development and ensures the contractor is following safe technical standards. NASA certifies the systems for flight prior to launch. With regards to operation, NASA is accountable for crewed portions of the mission, including lunar surface operations. The contractor manages other phases of the operations leading to the final lunar surface phase, which NASA controls.

b. Who is accountable for development performance, NASA or the contractor?

A: The contractor is responsible for development performance and is incentivized through milestone payments that are tied to specific deliverables in the contract schedule and which were negotiated between NASA and the contractor.

c. Who receives and controls the telemetry data for the entire end-to-end mission?

A: Both NASA and the contractor receive telemetry. The contractor controls telemetry during uncrewed portions of the mission. NASA assumes authority during crewed portions of the HLS mission.

d. Who is liable, if there is an accident, for damage to the lander, or injury of the astronauts?

A: Contract clauses require the contractor to carry insurance against harm to the astronauts, and any

failure to meet the contractual requirements of a successful mission results in non-payment or reduced payment of milestones.

e. Who is accountable for mission assurance and mission success?

A: NASA is responsible for the certification of flight readiness which is achieved through insight and data delivery documents from the contractor, including readiness reviews and verifications.

f. Who is accountable for systems engineering and integration on the lander?

A: NASA provides top-level requirements and standards that the lander provider must meet. The contractor is responsible for systems engineering with respect to their development. NASA is responsible for the certification of flight readiness which is achieved through insight and data delivery documents from the contractor. including readiness reviews and verifications. NASA also performs the systems engineering and integration required to ensure the HLS is integrated with other elements for Artemis Missions.

g. Who is accountable for mission operations?

A: NASA is responsible for lunar surface operations. NASA leads the Lunar Orbit Checkout Review. NASA is directly accountable during all crewed phases and indirectly accountable during uncrewed phases.

10. How much is requested in NASA's FY 2022 budget proposal for continued development of the Exploration Upper Stage for SLS Block 1B, which will allow for delivery of an additional 10 metric tons to trans-lunar injection orbit over the initial SLS configuration and Interim Cryogenic Propulsion Stage?

A: NASA has budgeted $479M in FY 2022 for continued development of the Space Launch System (SLS) Block 1B configuration with the Exploration Upper Stage (EUS).

11. NASA recently issued a solicitation for two non-NASA Private Astronaut Missions to the ISS per year.

a. What is the rationale for the solicitation?

A: Section 303 of P.L. 115-10, NASA Transition Authorization Act of 2017, provides the sense of Congress that, "An orderly transition for United States human space flight activities in low-Earth orbit from the current regime, that relies heavily on NASA sponsorship, to a regime where NASA is one of many customers of a low-Earth orbit commercial human space flight enterprise may be necessary..." Enabling private astronaut missions (PAMs) to the ISS is part of the Agency's goal to develop a robust low-Earth orbit economy where NASA is one of many customers, and the private sector leads the way. Creating this new regime will be dependent on bringing many new businesses and people into space, and will require the development of not only the supply of services but also the demand for those capabilities. Private astronaut missions will be dedicated missions that are privately funded, fully commercial spaceflights for enabling tourism, outreach, commercial research, and approved commercial and marketing activities on the space station. These missions will demonstrate and stimulate demand for future commercial destinations in low-Earth orbit. They will also help increase the U.S. crew vehicle transportation customer base to potentially decrease future transportation costs.

b. What costs will NASA incur related to the missions? Will NASA be reimbursed for

all costs incurred by the agency that are associated with the private astronaut missions?

A: The new pricing policy for PAMs reflects full reimbursement for all direct costs and the indirect costs that are above the ISS baseline capability. In other words, there will be a zero-percent subsidy for costs above the ISS baseline. Resources considered to be within the ISS baseline capability include on-orbit resources, such as visiting vehicle power, crew laptops and tablets, data downlink, and life support. Resources within the ISS baseline are not reimbursed. Resources considered to be above ISS baseline capabilities include crew supplies and food, upmass/disposal, integration, and ISS crew time.

The original June 2019 pricing policy provided a subsidized pricing model for the majority of the costs associated with PAMs. The original June 2019 pricing policy for PAMs was limited in scope and included only life support, crew supplies, stowage, power, data, crew time, and cargo upmass/disposal/downmass. NASA conducted a detailed assessment of the direct and indirect costs associated with PAMs. Based on the assessment and meeting the intent of the FY 2021 Joint Explanatory Statement ("NASA shall not use funds provided in this or any other Act to subsidize the cost of any project that is primarily intended for marketing, advertising, or entertainment purposes."), a new pricing structure was developed for PAMs. The original June 2019 pricing policy was retired on December 31, 2020. NASA updated the pricing policy website on January 26, 2021 to communicate to the public that the pricing policy was under review and would be updated. NASA also notified companies that all awards made after January 1, 2021, will be subject to the new pricing policy that was forthcoming. The pricing policy website provides the latest pricing, which was announced to industry in April 2021:

https://www.nasa.gov/leo-economy/commercial-use/pricing-policy

c. What are NASA's responsibilities and what are private astronaut entity responsibilities for these missions?

A: According to the PAM framework, NASA responsibilities are limited to ISS integration, interfaces, and ISS vehicle/crew safety.

- NASA is **NOT** certifying launch or spacecraft vehicles or processes and is only levying requirements and providing oversight for activities associated with ISS/ISS crew safety.
- NASA is **NOT** providing oversight, support, or certification commensurate with the Commercial Crew Program (CCP).
- No launch vehicle, free flight, or return/rescue requirements are being levied.
- NASA is providing ISS on-board resources and visiting vehicle/integration activities to enable PAMs.
- NASA is providing crew training and medical requirements that address ISS safety, use of habitability equipment, and life on ISS.
- NASA can also provide specialized service support, specifically requested by a PAM provider, on a reimbursable basis via reimbursable Space Act Agreements (SAAs) and/or Commercial Space Launch Act (CSLA) agreements (examples include Tracking and Data Relay Satellite System [TDRSS] satellite services for communications, fire/crash/rescue at the pad, parachute imagery, etc.).

PAM provider responsibilities:

- PAM crew safety for all phases of the mission.
- Flow-down liability requirements to the provider of the crew transportation vehicle and crew.
- Nominal and off-nominal launch and landing operations, including emergency rescue.
- Acquiring crew transportation and ensuring ISS requirements and verification for visiting

vehicles are met.
- Meeting all applicable local, national, and international laws and regulations.
- Providing supplies and resources independently, or via NASA, in accordance with the pricing policy.
- Providing real-time mission support with key positions (e.g., Mission Director, CAPCOM, etc.).
- Selection, training, and medical qualification of private astronauts commensurate with ISS requirements.
- Meeting all medical requirements and providing medical services for all aspects of the mission.
- Adhering to the required and agreed to liability regime, including participant informed consent and assumption of risk, cross waivers, and insurance requirements.

d. Who is liable for private astronaut activities on the ISS or for any damages incurred in the course of the missions?

A: NASA's standard PAM liability framework includes six major considerations: Federal Aviation Administration (FAA) licensing; cross waivers; private astronaut waivers; insurance protection for a private astronaut injury; insurance protection for NASA, International Partners, and property coverage; and third parties, which are discussed in more detail below.

- FAA Licensing: A PAM provider must flow down the requirements for their launch provider to obtain the proper FAA licenses. This includes the requirement to obtain liability insurance based on the FAA's maximum probable loss (MPL) calculations which includes pre-launch, launch, and re-entry.
- Cross Waivers: A PAM provider and its related entities are precluded from making claims against NASA and its ISS international partner agencies.
- Private Astronaut Waivers: Private astronauts and their estates are prohibited from making claims against NASA, the ISS International Partners, and associated entities and subcontractors. They also sign an Informed Consent and Assumption of Risk acknowledging acceptance of waivers and the risks of spaceflight and the mission.
- Insurance Protection for Private Astronaut Injury: A PAM provider is required to purchase liability insurance to protect ISS International Partners, NASA, and NASA subcontractors in the event that a private astronaut is injured.
- Insurance Protection for NASA, International Partners and Property Coverage: A PAM provider agrees to purchase insurance to cover damage to property and injury to people they or their private astronauts may cause to NASA Payloads, International Partner Hardware on ISS, and ISS Crew. Insurance amounts are predicated on market availability and NASA's quantification of risks. Self-insurance may also be considered for specific missions.
- Third Party: No insurance is required to cover third-party damages. PAM providers must indemnify NASA and the ISS International Partners against any third-party claims.

e. Will the entities carrying out the private astronaut missions be required to carry insurance for damages or injury, since these are not government-related missions? If so, what level of insurance will be required?

A: Yes – see the response to part d (above) for a description of the PAM liability framework. The specific level of insurance will vary based on the activities planned to be conducted during the specific mission.

12. As part of NASA's FY 2022 budget proposal, funding requested to stimulate commercial Low Earth Orbit demand would be transferred from the Commercial LEO Development program to the ISS Research program.

a. What is the reason for this move and for including commercial stimulus funding in the ISS Research program?

A: The demand stimulation activities are very closely aligned with the ISS National Laboratory activities managed by the ISS Program. Thus, the demand stimulation content was transferred to better align the budget and content.

b. Under the FY 2022 budget proposal, how much funding for commercial LEO demand stimulation would be transferred? Is that amount in addition to the previously planned FY 2022 funding for ISS Research in the FY 2021 request ($342.9 million minus the funding for biological and physical sciences transferred to the Science Mission Directorate) , or is some of the funding requested/transferred for commercial LEO demand stimulation coming out of the requested FY 2022 ISS Research budget?

A: The FY 2022 President's Budget Request (PBR) for ISS Research includes a $14M transfer (i.e., increase) from Commercial LEO Development and another $1.6M general increase to ISS Research.

($ in millions)	FY 2022
FY 2021 PBR ISS Research	342.9
Transfer of BPS	(79.1)
Transfer of Demand Stimulation	14.0
Increase for ISS Research	1.6
FY 2022 PBR ISS Research	279.4

c. How much in total is NASA requesting in FY2022 to stimulate commercial demand in Low Earth Orbit?

A: NASA is requesting $14M in FY 2022 to stimulate commercial demand in LEO.

13. In 2019, the Aerospace Safety Advisory Panel recommended that "NASA should begin an immediate transition to a next-generation Extra Vehicular Activity (EVA) suit system before the risk becomes unmanageable." Further, during a June 2021 ISS spacewalk, NASA astronaut Shane Kimbrough experienced issues with his space suit and had to return to the Quest airlock so they could be resolved.

a. How much funding, in the FY2022 budget proposal, is NASA requesting for an ISS spacesuit demonstration?

A: In the FY 2022 request there is $100M for development of NASA's next-generation spacesuits for ISS and Artemis missions and future deep space applications.

b. When will NASA be able to mitigate this serious risk to ISS astronauts?

A: The recent anomaly encountered on Shane Kimbrough's spacesuit that caused him to return to the airlock

during the June 2021 spacewalk is considered relatively minor and has been seen before. However, NASA always responds aggressively to anomalies during an extravehicular activity (EVA). NASA has embarked on an aggressive schedule in the recent Exploration Extravehicular Activity Services (xEVAS) solicitation to be able to conduct a demonstration in the 2025 timeframe on board the ISS and then begin a fleet transition starting in 2026.

14. According to the GAO's Assessment of Major Projects at NASA, one of NASA's space communications projects, the Space Network Ground Segment Sustainment, is over budget, has been descoped, has seen poor contractor performance, technical issues, and won't be compatible with the Artemis I mission. The latest estimate included in the GAO's report shows a cost increase of 127% and a 48-month delay over the baseline cost commitment in FY 2013. What are NASA's options and plans for addressing the performance failures on this contract?

A: Due to General Dynamics Mission Systems (GDMS) contract performance failures, NASA issued a partial termination to GDMS to achieve minimum success goals as defined in the June 2018 Continuation Review. Space Network Ground Segment Sustainment (SGSS) and GDMS have completed the transition to these goals, which included a Generation 2 TDRS and its required mission set. With the completion of minimum success goals, the SGSS project is in the final stages of closing out the GDMS contract. All hardware has been transitioned to the Advanced Communications Capabilities for Explorations and Science Systems (ACCESS) project. The SGSS Main Mission antennas #2 through #6 and full success activities (White Sands complex) will be completed as an ACCESS sustainment effort utilizing existing SGSS funding to achieve completion of SGSS upgrades.

15. The Administration is requesting an 80% increase over FY2021 enacted appropriations for a Communications Services Program (CSP) as part of a strategy to "migrate near-Earth missions from communications and navigation services provided by government-owned networks to commercial networks," according to the Congressional Justification document.

a. Please provide more information on the strategy and implementation plan for CSP.

A: The Communications Services Program (CSP) completed the necessary Agency processes to develop an acquisition strategy and prepare a funded Space Act Agreement partnership announcement. The final announcement was released on July 21, 2021 and proposals were due on September 3, 2021. CSP expects to award multiple agreements for demonstrations in early FY 2022. The funding increase from FY 2021 is for these awards. Partners will be required to execute end-to-end in-space demonstrations with a representative spacecraft to fully validate the commercial capabilities; limited ground-based testing would be insufficient. NASA expects proposers to provide their own representative spacecraft or other appropriate in-space platform as part of the demonstration. The requested funding increase is necessary for partners to develop or modify their existing commercial capabilities and to begin development for the in-space demonstration.

CSP will monitor partners' progress to meet the fixed-price milestones negotiated in their agreements. With multiple awards, NASA expects varied schedules encompassing an overall three- to four-year demonstration period. Knowledge gained through the demonstration phase regarding commercial technical capabilities, operational models, business models, security posture, and other areas will inform the subsequent acquisition strategy and a separate solicitation for services. Given the rapid evolution of this market, it is expected that CSP will pursue a second round of demonstrations to validate additional capabilities beneficial to commercial users and the Agency.

TDRS services will begin to degrade in the early 2030s. The overall schedule posture is necessary to ensure the commercial capability is available before transitioning from TDRS. Although a transition strategy is in place, as represented by the CSP demonstrations, the Space Communications and Navigation (SCaN) Program is developing a tactical plan that considers projected TDRS fleet lifetimes, existing/committed missions that require TDRS services, and new users who could appropriately use commercial satellite communication (SATCOM) once successfully demonstrated.

Services demonstrated through CSP will eventually be procured by a single NASA office responsible for acquiring near-Earth communications services, regardless of whether they rely on an in-space relay or transmit data directly to Earth. In other words, the long-term vision is for the segregation between the Near Earth Network and Space Network to be dissolved, and have one technology-agnostic acquisition function for near-Earth communications services.

b. What requirements does NASA's CSP strategy include for cybersecurity, given that commercial entities could eventually be handling communications involving human spaceflight operations?

A: The SCaN Program has a robust Network Integrity Office to ensure secure end-to-end communication capabilities are developed and maintained for the Agency. The Network Integrity Office provided a security questionnaire incorporated into the CSP announcement that will be responded to by each proposer. The security questionnaire is based on a U.S. Space Force Commercial Satellite Communication process that was provided to NASA. As part of the CSP demonstrations, NASA will negotiate appropriate security-related milestones and deliverables to evaluate each partner's overall security posture to ensure they are compliant with all Federal regulations and Department of Homeland Security directives. As NASA transitions to the future procurement of services, security requirements will be incorporated into subsequent solicitations and service contracts.

c. Have you performed an analysis of the expected cost savings to be realized from the CSP initiative? If so, please provide that analysis to the Committee.

A: At this time, the service cost information for commercial SATCOM services is not firmly known. The CSP demonstration partners will be asked to provide business case analysis, pricing models, and pricing estimates to close the knowledge gap. Any information provided by the awardees in the demonstration phase will not obligate them in the service acquisition phase if they choose to respond to the planned subsequent solicitation. As the TDRS transition plan is developed, cost estimates of the overall transition that incorporate TDRS sustainment costs, user transition costs, and estimated commercial SATCOM service costs will be developed.

16. What is NASA's current estimate of the scientific impact of the out-of-band emission limits agreed upon at the World Radiocommunication Conference 2019 (WRC-19) into the 23.6-24.0 Gigahertz microwave band, protected for passive Earth remote sensing, including space-based water measurements critical for weather forecasts and climate monitoring?

a. What are the major challenges for NASA, across the agency, on spectrum management, and how is NASA working to address them in the long term?

A: The 23.6-24 GHz band has historically been relatively free from major interference issues and has been used extensively by NASA in our Earth Science missions, including those that make observations relevant to weather and climate. Adjacent band services have generally complied with the limits set forth under international and domestic regulations. This is critical for NASA observations because even low levels of interference can contaminate the observations and be undetectable, which leads to erroneous data being used

in research, weather prediction, climate models, and applications used by other U.S. agencies. The source of interference into the 23.6-24 GHz band (from out-of-band emissions) is also not detectable by the passive sensor, which makes attribution of interference nearly impossible.

To date, NASA does not have sufficiently detailed commercial broadband deployment information regarding future mobile systems that may operate in the adjacent band, and that may introduce increased out-of-band emissions, to perform an updated detailed, quantitative impact assessment. To perform such an assessment, NASA would require details about device designs as well as system deployment, including the number, location, and emission characteristics of deployed base stations and subscriber systems. Given these factors, the complexity of numerical weather forecasting and climate modeling processing, and the significant variety of other applications that use these data, we cannot isolate the impact from any specific interference event. In summary, given the information in hand, NASA does not have an updated, definitive quantitative estimate of impact at this time.

Despite these uncertainties, using the final limits agreed to at World Radiocommunication Conference-19 (WRC-19), Earth Exploration Satellite Service (EESS) (passive) will receive increased levels of interference. NASA's ability to meet threshold objectives will depend both on the number of networks deployed within the view of the satellite and what individual limits each of the networks achieve. Further, it is unclear how many mobile networks will be deployed using the relaxed limits vs. the final limits. This will also have a large effect on the actual interference environment in which NASA's current and future satellites will operate.

b. What is NASA's FY2022 total budget request for spectrum management and radiofrequency interference (RFI) impact assessments and mitigation for its operations and development programs?

A: The NASA FY 2022 President's Budget Request (PBR) includes $10M annually within SCaN for the office which oversees Agency-level spectrum management. The funds primarily support the statutory and regulatory requirements and processes, both domestic and international, to authorize NASA's radiofrequency systems and to maintain continued access to the spectrum.

Outside of the Agency-level functions, direct project and facility spectrum activities are supported by Center and Project operational funds, including funds for each NASA Center's Spectrum Manager. As a specific spaceflight example, NASA's Earth Science Soil Moisture Active Passive (SMAP) mission assesses the measured science data in the 1400-1427 MHz band to identify potential radiofrequency interference (RFI), is funded within that mission's operational budget.

There isn't a separate accounting line item across the Agency that provides a complete estimate of NASA spectrum-related activities, including those specifically associated with RFI impact assessments and mitigation at the Center and Project level.

17. Now that the Biological and Physical Science (BPS) program is managed under the Science Mission Directorate, how is NASA supporting effective translation of BPS' scientific knowledge into human exploration plans and development programs?

A: The office of the Human Exploration and Operations Mission Directorate (HEOMD) Systems Engineering and Integration (SE&I) Deputy Associate Administrator is responsible for ensuring the overall HEOMD strategy is reflected in program requirements; leads architecture, formulation, mission planning; and provides technical direction for HEOMD activities (Moon, Mars, and other human spaceflight missions). The duties of the HEOMD SE&I office include planning and gap analyses of capabilities required for future HEOMD missions. On an annual basis, the capability gaps are re-evaluated, including interfacing with other Mission Directorates in order to identify how recent

knowledge advancements may be incorporated into the current human exploration plans and development programs.

NASA's Biological and Physical Sciences (BPS) Division maintains close ties to the Human Exploration and Operations Mission Directorate's Systems Engineering and Integration office, Advanced Exploration Systems Division, and the Human Research Program (HRP). These close ties include frequent standing meetings, representation on committees (e.g., Human Systems Risk Board, Crew Health and Performance Committee, Exploration Integration Panel, and Utilization and Coordination Integration Group), workshops, co-mentoring interns, joint science solicitations, and data sharing. BPS is also currently working with HRP to include science objectives in the HRP roadmaps that will address the scientific translation across Divisions and space missions.

18. Many of NASA's ongoing and proposed Aeronautics programs and initiatives involve community engagement and response testing in areas such as noise acceptance, infrastructure conditions, and air traffic management. Given the importance of community and stakeholder engagement for technology adoption, how is NASA ensuring engagement with underrepresented and underserved communities?

A: The primary goal of NASA's Low Boom Flight Demonstration (LBFD) Mission is to gather survey data that will be used to help define new standards and regulations for supersonic flight over land. NASA recognizes the importance of ensuring this data is representative of the diversity in the U.S. population. The LBFD team has recently awarded a contract to a team that will support our community test planning. The team is nationally known, and has recent experience conducting an extensive, nationwide airport noise survey for the Federal Aviation Administration (FAA). Although the effort to develop the LBFD survey plan is just beginning, NASA intends to work closely with the contractor team to ensure that a diverse population, including underrepresented and underserved communities, is invited to participate in the LBFD community test. Opportunities to participate go beyond the survey process and include community engagement and science, technology, engineering, and mathematics (STEM) education. The LBFD team has partnered with NASA's Communications and Education organizations to identify opportunities that ensure diverse populations are included in these activities as well.

The Aeronautics Research Mission Directorate's (ARMD's) Advanced Air Mobility (AAM) planning efforts are seeking ways to support the early adoption of public-good missions. These efforts include developing use cases and forging partnerships with companies focused on these missions. Examples of public-good missions of interest include the transport of patients from areas not easily serviced by ground-based ambulances, the transport of doctors to the patients in areas where medical services aren't readily available, the rapid transport of organs for transplant, and time-critical laboratory sample delivery. Some of these public-good use cases can have particular benefit for underrepresented and underserved communities.

NASA's AAM team is directly engaging with local communities on several fronts. ARMD has recently signed collaboration agreements with five local, state, and regional departments of transportation (DOTs), in Ohio, Massachusetts, Minnesota, North Central Texas, and the City of Orlando, Florida. These agreements are initially focused on supporting the partners' efforts to incorporate AAM into their local transportation plans. Having AAM integrated into these plans is critical to both provide resilient transportation services to the entire community and also to enable these DOTs to plan AAM infrastructure to reach communities not already well served by existing transportation options. ARMD will make the lessons learned from these partnerships publicly available so that all states and localities can benefit. ARMD is already engaging with multiple other DOTs to cross-pollinate knowledge and thus advance all communities.

ARMD has also created the AAM Ecosystem Working Groups (AEWG). The four working groups within the AEWG are dedicated to providing information and facilitating discussions across not only the companies seeking to realize AAM, but also more broadly to any interested party, including members of local communities where AAM operations in occur. Presentations have included overviews of what AAM is envisioned to look like and provided aviation system knowledge as a foundation for members of the public to actively engage in the planning for local AAM operations within their community. For further information, please see the following link: https://nari.arc.nasa.gov/aam-portal/

ARMD has funded several Small Business Innovation Research (SBIR) efforts to integrate local weather data collection and forecasting at the community level. These efforts are intended to support both future AAM operations, which will require more local weather information than is currently available, and local community needs. Supplementing existing National Oceanic and Atmospheric Administration (NOAA) and other weather monitoring systems with additional data collection capabilities can support the early identification of weather-related hazards, such as flooded roads, and inform other local community efforts to ensure the safety of their citizens. Having multi-purpose systems providing services to multiple stakeholders reduces the costs to each stakeholder and will allow broader deployment of these systems across underrepresented and underserved communities.

Within the Airspace Operations and Safety Program, NASA is directly partnered with U.S. airlines and industry in joint development and demonstrations to enable early and streamlined technology adoption and transfer. The program has transferred several technologies for advancement of aviation efficient operations and enhanced safety to the FAA, airlines, and industry. In addition, the program is currently partnered with American Airlines, Southwest Airlines, Delta Air Lines, FedEx Corporation, United Parcel Service, United Airlines, the Air Traffic Control Association, National Air Traffic Controllers Association, Airlines For America, the Flight Safety Foundation, Charlotte Douglas International Airport, Dallas Fort Worth International Airport, and Dallas Love Field Airport, as well as the broader aviation manufacturer and airframe industry for joint development and demonstration of ongoing and future research. These tools developed by NASA, airlines, airports, and the FAA will support the ability to be responsive to community needs related to airline operations.

19. The National Academies of Sciences, Engineering, and Medicine released a report in 2020, "Assessing ULI's Progress toward Meeting its Goals," that assesses the NASA Aeronautics University Leadership Initiative (ULI). The report made several recommendations, including better aligning with university needs, providing transparency on student participation, and increasing participation in the program by underrepresented minorities, women, HBCUs, and MSIs.

a. Please provide NASA's response to the recommendations from the National Academies for the University Leadership Initiative.

A: NASA contracted with the National Academies of Sciences, Engineering, and Medicine to review the execution and performance of the University Leadership Initiative (ULI). Valuable recommendations emerged from the report in areas of diversity and inclusion, outreach, training regarding implicit bias, increased use of social media to promote university successes and future opportunities, and improvements to the proposal solicitation for clarity around important topics such as intellectual property. ULI has enhanced its processes to address these opportunities for improvement, and a high-level summary of the key take-aways and subsequent actions pursued by ULI is provided here.

In the area of Diversity and Inclusion, all recent awards have included Historically Black Colleges and Universities (HBCU) and Minority Serving Institutions (MSI) universities as members of the teams.

Fifteen underrepresented universities are participants in ULI with two of them as Principal Investigators (PIs) leading an award. Presently, we have two female PIs representing 11 percent of the current awards – a number that ULI is striving to increase. In addition, eight of the 19 PIs in our current awards are new grantees with NASA serving to increase our broad reach and attract new research talent to the Agency. The teams continue to grow to include about 20-50 students each, with about half of them at the undergraduate level, serving as an excellent mechanism to develop the Nation's future aeronautics workforce. ULI now supports research representing 34 U.S. states plus the District of Columbia across the 19 awards issued to date, reaching talent reflecting the broad diversity of the Nation.

In other areas for improvement mentioned in the report, ULI is continuing to improve awareness of ULI opportunities and encourage participation by increasing outreach to many organizations suggested in the report (Women in Aerospace, Institute of Electrical and Electronics Engineers [IEEE]/Women in Engineering, the National Society of Black Engineers, the Society of Hispanic Professional Engineers, and the Society of Women Engineers, among others). ULI is working to prevent implicit bias by offering training to its proposal reviewers, and will continue to provide post-review feedback to all applicants to improve proposal quality and support growth of young faculty. In addition, ULI will look for ways to increase its existing efforts in the use of social media to showcase ULI success stories, and will encourage project teams to present at major conferences to reach out to the aeronautics community.

b. How is the ULI program balancing transitioning research to industry partners while also meeting the needs of academia in terms of disseminating research and training students?

A: ULI is structured to give universities the responsibility to define their research agenda and establish their goals. This requires balancing research transition to industry partners while also meeting the needs of academia in terms of disseminating research and training students. To this point, the ULI teams have been quite successful in balancing the two objectives. Publications have been plentiful across all teams, and there have been numerous presentations and special sessions annually at key national technical conferences focusing on the outcomes of these ULI awards. Every ULI team is comprised of industry and Government partners to address the opportunity for their research products to transition to applications in industry and elsewhere. Each team has engaged partners within the traditional aviation community and outside of traditional aviation companies for the appropriate technology development and transfer. Teams have been encouraged to pursue start-ups and emerging market players, if appropriate for their development objectives. ULI has long supported this approach by developing and making widely available a Potential Partners List on its webpage. To support transition of research products to NASA projects and programs, ULI invites ARMD projects to participate in university annual review meetings, and also sponsors faculty visits and talks at NASA research Centers for direct engagement and sharing with NASA subject matter experts. In its entirely, these approaches have led to a well-balanced program where objectives of research dissemination and technology transfer are effectively met.

20. NASA conducts education and STEM engagement activities across the agency's portfolio, and not only within the Office of STEM Engagement. Does NASA have an agency-wide strategy and/or management structure for its STEM education activities?

A: NASA's STEM engagement efforts are coordinated across the Agency by NASA's STEM Engagement Council (SEC). The SEC ensures a comprehensive strategy and coordinated Agency-wide approach to develop and deliver the Agency's STEM engagement efforts. The NASA Associate Administrator (AA) for STEM Engagement within OSTEM serves as the SEC Chair, and the SEC includes members from NASA's Mission Directorates, field Centers, and functional offices across the Agency. The SEC was established in 2018 and created its first Agency-wide strategy in 2018; the NASA Strategy for STEM Engagement was updated and published in April 2020 and will guide NASA's STEM engagement work through 2023. See:

- https://www.nasa.gov/sites/default/files/atoms/files/nasa-strategy-for-stem-2020-23-508.pdf

In alignment with NASA's goals and objectives for STEM engagement (see page 5 in the document at the link above) and Federal Government evidence-based policy initiatives, NASA's Office of STEM Engagement implements a comprehensive performance assessment and evaluation strategy for its work that includes a Learning Agenda. The OSTEM Learning Agenda is a systematic approach to identifying gaps in knowledge and conducting research to generate knowledge to fill these gaps through collaborative, iterative processes. The Learning Agenda provides a more robust, comprehensive approach to understanding the scope and impacts of investments, and generates a portfolio of evidence that includes evaluative studies; literature reviews; benchmarking studies; and output, outcome, and milestone performance measures. The portfolio of evidence that is generated through the execution of the Learning Agenda is used to inform evidence-based budgetary, programmatic, and operational decisions. The Learning Agenda serves as the foundational document for building a culture of learning and continual improvement within NASA's OSTEM. The implementation of the Learning Agenda provides a systematic approach for building and using new knowledge about project and operational performance for evidence-based decision-making and continual improvement.

21. The Science, Space, and Technology Committee has been working on a bipartisan basis in recent years to address the risk of undue foreign influence in the U.S. research enterprise. We, together with colleagues on the House Armed Service Committee, wrote an April 2021 letter to President Biden, and we have consistently pushed for an approach that balances the need to address legitimate security risks with the importance of maintaining a research ecosystem that is open, collaborative, and welcoming to research talent from around the world. An aggressive approach to foreign influence could potentially lead to false accusations and negatively affect NASA's ability both to compete for global talent and to stay true to its core value of inclusion and maintain an environment that is welcoming and safe for all. As NASA Administrator, what is your approach to addressing the risks of undue foreign influence in the U.S. research enterprise, while maintaining the benefits of an open, collaborative, and welcoming research environment?

A: When NASA was created in 1958, its founding legislation, the National Aeronautics and Space Act, directed the new Agency to pursue cooperation "with other nations and groups of nations." This principle of international cooperation has been a guiding philosophy for NASA, and it has never been more important than it is today. Such collaboration has been and will be even more essential to addressing the increasingly global and interrelated scientific challenges that will face us in the years ahead: expanding human exploration beyond the frontiers of low-Earth orbit; broadening human knowledge by answering profound questions about the Earth and the universe we live in; solving technical issues related to air traffic management, aviation safety, and the impact of aviation on climate and the environment; and leveraging technology investments to push the boundaries of innovation.

NASA has always sought the widest practical and appropriate distribution of information about and data from our programs in a public manner in accordance with scientific practice and American values of openness and transparency. The Agency constantly works to strike the right balance between needing to protect sensitive export-controlled technologies and information, while also sharing the results of our research openly and broadly in order to advance science and further our international and public partnerships. In doing so, NASA abides by all Federal laws, including export control and intellectual property laws, and we expect our external partners to do the same. In addition, NASA takes the appropriate steps to protect its export-controlled and intellectual assets through steps such as screening all foreign visitors to NASA's facilities and all recipients of export-controlled NASA technologies for export control, nonproliferation, and counterintelligence risks by NASA's export control and security officials.

A major part of NASA's counterintelligence program is the identification of foreign adversarial threats and the provision of defensive counterintelligence support to all mission and scientific programs within the Agency. NASA counterintelligence officials do this in concert with national and international counterintelligence community counterparts. While such counterintelligence information is kept internal for national security reasons, NASA works closely with the Federal Bureau of Investigation (FBI), which has taken an active role in warning the academic community about foreign threats to their research and development (R&D) and informing institutions and researchers what they can do to prevent or mitigate those threats.

It is important to note that NASA generally does not fund foreign research and has advised all contractors and grantees, including hundreds of U.S. universities that might otherwise receive NASA sponsorship for fundamental scientific research, that NASA funding cannot be given to or used by individuals or organizations subject to sanctions; entities prohibited by U.S. law; foreign nationals specially designated by the U.S. Department of Treasury; or those who are from countries determined by the U.S. State Department to be State Sponsors of Terrorism. NASA reserves the right to have U.S. grantees certify that no Agency money will be used to fund research conducted by these prohibited groups.

Twenty-six years ago, NASA established one of the first Agency-wide export control programs in the U.S. Government, in order to ensure our responsible stewardship of the advanced technologies and capabilities which NASA has developed and with which we are entrusted by other U.S. Government agencies and international partners. Today, every international agreement into which NASA enters includes interagency-approved export control provisions to ensure that both NASA and its foreign partners safeguard the technologies shared in the partnership, while also restricting retransfers of export-controlled goods and technologies without prior authorization.

NASA abides by an ongoing restriction in law limiting the use of NASA funding for bilateral activities with China or Chinese-owned companies. As a result, interactions with China are extremely limited. Also, in accordance with these legislative restrictions, official Chinese visitors are prohibited from visiting a NASA-owned or -utilized facility unless certified to Congress in advance of such a visit. These restrictions broadly apply to persons affiliated with Chinese organizations. In very limited circumstances, NASA interacts bilaterally with officials of the Government of China when such interactions benefit the Agency and when NASA has certified in advance to Congress. NASA takes steps to review, strengthen and broadly implement the Agency's statutory restrictions related to China, including in NASA's procurements and grants.

Prior to initiating any bilateral interactions with China, NASA consults with the FBI to ensure that such interactions:

(1) pose no risk of resulting in the transfer of technology, data, or other information with national security or economic security implications to China or a Chinese-owned company; and
(2) will not involve knowing interactions with officials who have been determined by the United States to have direct involvement with violations of human rights.

The Office of Science and Technology Policy is leading development of implementation guidance for the National Security Presidential Memorandum (NSPM-33) concerning R&D supported by the U.S. Government. The stated purpose of NSPM-33 is to "strengthen protections of United States Government-supported R&D against foreign government interference and exploitation" while "maintaining an open environment to foster research discoveries and innovation that benefit our nation and the world." The U.S. Government, including NASA, will adhere to this guidance.

Consistent with NASA policy and procedures, all foreign nationals seeking access to NASA facilities and/or non-public-facing information technology (IT) resources are subject to – and have passed – screenings under NASA's security protocols, including a series of database checks for each individual to identify persons who should be denied access. Typically, foreign nationals are affiliated with U.S. academic and research

institutions working with NASA on a specific program, project, or activity, as well as NASA internships and fellowships. If granted physical access to NASA, foreign nationals from designated countries must be escorted at all times while on NASA property. Additionally, once on site, all visitors must meet and maintain all safety, physical security, IT security, and other training requirements specified by NASA. With the exception of those foreign nationals from countries identified in NASA's Designated Country List, decisions to grant physical or logical access to NASA are made at NASA Centers on a case-by-case basis to ensure the requests conform to Agency and Federal policies and regulations, including U.S. national security, export control, nonproliferation, and foreign policies and regulations. Visitors from countries identified in the NASA Designated Country List, such as China, are subject to additional scrutiny from NASA Headquarters. Consistent with NASA Procedural Requirements 1600.4A, and longstanding policy, foreign nationals from countries designated by the U.S. Secretary of State as sponsors of terrorism generally are not eligible for physical or logical access to NASA.

More information about NASA's Foreign Nationals Access processes can be found here:
https://nodis3.gsfc.nasa.gov/displayDir.cfm?Internal_ID=N_PR_1600_004A_&page_name=Chapter4.

The current list of NASA-designated countries is available at:
https://oiir.hq.nasa.gov/docs/Designated_Country_list_6-21-2019_tagged.pdf

22. During the question and answer portion of the hearing, Representative Stansbury referred to a Majority staff report issued by this Committee in March of this year found that, within NASA's own STEM workforce, male employees outnumbered female employees by a 3-to-1 ratio, and white employees similarly outnumbered racial and ethnic minority employees by 3-to-1 as well. Why does NASA have these disparities in its agency STEM workforce, and what in the FY2022 budget request is NASA proposing to address them?

A: First, I want to thank the committee for their work on this important issue. I am committed to ensuring diversity, equity, inclusion, and access (DEI&A) throughout NASA. NASA missions are incredibly challenging, and we must engage with every corner of this nation to realize these bold goals. I am committed to ensuring that the NASA workforce and its leadership reflects America. For the first time ever, NASA has a senior advisor for DEI&A and our FY 2022 budget requests increased resources for DEI&A. NASA's Office of Diversity and Equal Opportunity received a $5 million plus-up in the FY 2022 budget request. With that funding, NASA will be able to significantly enhance its service levels for Diversity, Equity, and Inclusion (DEI), including for: (1) engaging underserved communities and improving equity in NASA's administration of grants to external institutions that conduct science, technology, engineering, and mathematics (STEM) research (e.g., colleges and universities); (2) improving DEI data/analytics capabilities; and (3) implementing the President's new Executive Orders and Memoranda on DEI.

NASA employees – regardless of age, gender, and racial backgrounds – cite shared values, commitment to the mission and loyalty to NASA as key reasons why they feel positively about their jobs and why they stay at NASA. However, this low attrition rate also means NASA has had fewer opportunities to bring onboard new hires in the past to diversify our workforce. At NASA, we have many women and people of color serving key leadership positions, and we are focused on putting the first female and person of color on the Moon. Additionally, over the past five years, the percentage of females in Science and Engineering disciplines within NASA has increased by two percent. That said, we are continually seeking new ways to increase diversity in our ranks, whether that be diversity in terms of age, experience, gender, race, social background or even ways to problem solving.

NASA senior leaders are working on a multi-year, overarching strategy that will provide more agility across our overall workforce, including increased talent mobility and investment in non-permanent civil service appointments to support shorter-duration projects and projects where required skills and knowledge change

rapidly. Additionally, we are looking at new ways of bringing on new talent to the Agency. In particular, NASA's Office of Human Capital has implemented several new tools that Centers and Mission Support Enterprise Offices are using to aid them as they create the workforce that is efficiently shaped and sized to meet the needs of the future. These tools include:

- Enhanced hiring flexibilities including direct hire authority, which provides greater reach to external talent and faster time to hire;
- Talent Marketplace – an internal application where detail and lateral opportunities are shared with the workforce; and
- Increased use of rotations, temporary assignments, and promotions, and just-in-time training to upskill, reskill, or broaden capabilities of the existing workforce.

NASA's Office of Diversity and Equal Opportunity (ODEO) is actively involved in this strategic workforce planning effort, while also continuing to lead NASA diversity and civil rights policies, programs, and services.

Submitted by Mr. Beyer

1. **During the question and answer period of the hearing, in response to my question about the May 2021 report of the Government Accountability Office (GAO) on NASA's Artemis and lunar programs, you stated that "that report was written before some of the changes that had occurred, so parts of that report are dated."**

    a. **Please provide a list of what is out of date in the report, and why.**

A: The life cycle of the Government Accountability Office (GAO) Lunar Programs audit (GAO 21-330) spanned from the March 2020 kickoff to publishing of the final report in May 2021. The audit's main data collection period concluded in early February 2021. Certain areas reflected in the GAO final report have since experienced new progress and changes.

Some areas from the report that demonstrate this progress include, but are not limited to:

- Minimized requirements for Human Landing System (HLS)
    - NASA is currently working sustaining requirements with Lunar Exploration Transportation Services (LETS) which would allow NASA to buy routine astronaut transportation services throughout the campaign of Artemis missions.
    - NASA conducted the Acquisition Strategy Meeting (ASM) for recurring/sustaining services procurement (Next Space Technologies for Exploration Partnerships [NextSTEP] Appendix N Broad Agency Announcement [BAA] / LETS); follow-on ASM (Aug. 2021) to report Request for Information (RFI) results and approve Appendix-N/LETS acquisition strategy.
- Definition of top-level requirements
    - An update to HEOMD Top Level requirements document 004 (HEO-004) was approved at a joint Exploration Systems Development/Advanced Exploration Systems control board on January 28, 2021, followed by HEOMD-level approval on March 16, 2021.
    - The synchronization review noted in GAO's final report "to help ensure that requirements between mission and program levels are reconciled," was held in Fall 2021, as noted in the report.
- Management structure and practices
    - NASA announced a reorganization on September 21, which separated HEOMD into the new Exploration Systems Development Mission Directorate (ESDMD) and Space Operations Mission Directorate (SOMD). ESDMD has the responsibility for development programs supporting deep space exploration, including Artemis missions. SOMD will focus on launch and space operations. The current roles and responsibilities will remain in place until the specifics of the new organizations are rolled out in early FY 2022.
- System integration
    - This has been clearly defined. The integration approach briefing was approved by the Agency Program Management Council. Aspects of the integration approach are currently being codified in the Advanced Exploration Systems' Systems Engineering Management Plan (SEMP) and other plans.

2. **The GAO report notes that Artemis is not being managed as a "formal program" that would follow NASA's program management policy. As such, "the agency lacks a finalized roadmap for how it plans to manage the effort." What is NASA's current approach to managing Artemis and are you considering making it a formal program?**

A: In September 2020, NASA released for Congress and the general public a detailed description for the strategy and planning of Artemis called "Artemis Plan, NASA's Lunar Exploration Plan Overview" (https://www.nasa.gov/sites/default/files/atoms/files/artemis_plan-20200921.pdf). The Artemis Plan described the goal of an initial human lunar landing by 2024 with acceptable technical risks, while simultaneously working toward sustainable lunar exploration. It included the multi-year strategy for lunar

exploration, science, and technology including major milestones, development activities, and core mission elements.

Multiple Mission Directorates within the NASA support the Artemis missions. The Space Technology Mission Directorate develops new technologies to enable human and robotic exploration of the Moon, Mars and beyond, and enhances research and development at NASA to maintain and enhance U.S. leadership in space technology. NASA's Science Mission Directorate's Lunar Discovery and Exploration Program is working with several American companies to deliver science and technology to the lunar surface through the Commercial Lunar Payload Services (CLPS) initiative. During the Artemis missions, early commercial delivery missions will perform science experiments, test technologies, and demonstrate capabilities to help NASA explore the Moon and prepare for human missions.

NASA officials established well defined organizational responsibilities for Artemis missions. The Exploration Systems Development (ESD) Division is responsible for Artemis I and II mission planning and integration. The Advanced Exploration Systems (AES) Division is responsible for the Artemis III and beyond mission planning and integration, with ESD responsible for providing the crew transportation services, including the SLS launch vehicle, Orion crew capsule, and ground support. In addition, NASA established a HEOMD-level Systems Engineering and Integration (SE&I) organization responsible for definition of Directorate-wide design and verification requirements.

NASA has not designated Artemis as a program. It is a series of missions where each mission includes an integrated set of programs and/or projects, each of which apply NASA Procedural Requirement 7120.5 programmatic policy, and the integrated mission is reviewed via Flight Readiness Review (FRR) and Certification Of Flight Readiness (COFR) processes before launch.

The NASA Federated Board, led by the deputy heads of three Missions Directorates — Human Exploration and Operations, Science, and Space Technology, ensures Agency alignment and coordination with Agency strategic direction and helps to define and implement Agency priorities. The Federated Board focuses on technical integration and coordination activities around the goals of a long-term lunar surface presence beyond the first lunar landing mission and the first human mission to the surface of Mars; activities include:

- Cross-Directorate coordination and implementation of Agency strategic guidance.
- Out-year planning integration, including future architecture definition and planning.
- Long-term strategic assessments to inform NASA's strategy.

3. The GAO raised concerns about the high technical risks of the Solar Electric Propulsion System for the Gateway's Power and Propulsion Element. What is the current status of NASA's solar electric propulsion technology, in terms of readiness level, cost, and schedule, and how is it affecting the Gateway capabilities and schedule?

A: The Solar Electric Propulsion (SEP) technology thruster developed under the Advanced Electric Propulsion System (AEPS) contract is a flight design that is heavily based on the well-demonstrated NASA technology development unit; the thruster's Critical Design Review is planned for mid-FY 2022. Environmental and performance testing and modeling of the thruster engineering testing units are complete, and those tests have successfully demonstrated that the AEPS thruster design meets or exceeds performance requirements. The Human Exploration and Operations Mission Directorate (HEOMD) Gateway Power and Propulsion Element recently levied updated requirements that align with the Gateway mission and no major technical issues have been identified. The Aerojet Rocketdyne response to the updated requirements, including the proposed AEPS thruster qualification and flight schedule, is currently being evaluated by NASA.

4. **Regarding the GAO report, what is the status of NASA's progress on developing guidance to mitigate risks associated with delaying the establishment of high-level requirements early in the acquisition process when using service-type contracts, and when will that guidance be incorporated it in NASA's reference guide, as recommended by the GAO?**

A: The estimated completion date of the reference guide is May 2022. The Office of the Chief Engineer (OCE) is in the process of identifying the team to develop the guide. The team will help outline and determine contents of the guide, develop the content, and review prior to OCE's planned publication by the estimated completion date.

   a. **What is the status of NASA's progress in conducting and executing the process used to determine the program and technical management practices and tools that it will apply to the Artemis III and later missions, as recommended by the GAO?**

A: NASA considers it essential to document the process for how the AES Division will manage and integrate the programs involved to successfully complete those missions, and the programmatic and technical management practices and tools that will be applied. NASA will provide documentation of the key practices, tools, and resulting products used for the integration and conduct of the Artemis III and subsequent missions. The evidence of the enacting of this recommendation is the completion of the first AES integrated synchronization in Fall 2021.

5. **What funding is requested in NASA's FY2022 budget request for orbital debris activities, and what additional orbital debris-related activities will be addressed with the proposed funding increase?**

   a. **How will NASA's orbital debris activities, as described in the Congressional Justification document, "lay the groundwork for addressing this growing environmental problem?"**

A: The NASA Orbital Debris Program Office typically receives about $7M annually to support the following orbital debris mitigation activities:

- Orbital Debris (OD) Measurements – Monitor the ever-changing OD environment with radar, telescope, *in situ*, and other measurement activities;
- Orbital Debris Modeling – Develop and update modeling and mission support tools, which are used by hundreds of operators (NASA, U.S. Government, commercial), academia, and research groups around the world;
- Mission Support – Oversee NASA mission compliance with OD mitigation requirements; and
- U.S. Government Interagency Support, International Support, Outreach – Provide interagency, international, commercial, and outreach support to collectively manage the orbital debris problem.

NASA's proposal for a $3M budget increase is to enhance and sustain the Orbital Debris Program Office key activities, specifically:

- Acquire, process, and analyze radar data to bridge the observation gap that exists with centimeter-sized (cm-sized) debris in low-Earth orbit;
- Improve Eugene Stansbery–Meter Class Autonomous Telescope operations to extend the Department of Defense's (DoD's) Space Surveillance Network coverage (~1 meter) for debris down to 15-20 cm in geostationary orbit;
- Expand efforts to process/analyze laboratory impact test data to characterize debris size/mass/material/shape distributions down to 1 millimeter (mm);

- Advance Technology Readiness level of the Multi-layer Acoustic & Conductive-grid Sensor (MACS) which will detect hypervelocity particle impacts of 50 microns or larger in preparation for a future mission opportunity;
- Develop a new debris shape distribution for model implementation to improve OD risk assessments; and
- Conduct new laboratory material experiments to improve fidelity of satellite reentry analyses.

b. During the question and answer portion of the hearing, in response to my question about space traffic management (STM) and orbital debris, you stated that NASA is "working on technology that will help us get those pieces of debris out." How much funding is NASA proposing in the FY2022 budget request to support R&D for active debris removal or mitigation?

A: NASA acknowledges the challenge of orbital debris caused by defunct spacecraft and is actively participating alongside the stakeholder community as we evaluate technological and policy solutions to this global challenge. The Agency has a robust strategy addressing orbital debris that encompasses executing a long-standing program to monitor, predict, and protect our assets, to the best of our ability, and developing new technologies that enhance our capability to operate safely in space. The Agency's technology development includes ongoing projects and consideration of new technology development activities, such as advanced ground-based and *in situ* debris measurement capabilities, innovative multi-purpose spacecraft impact protection shielding material, and low maturity orbital debris remediation concepts.

With regard to active debris removal technologies, NASA continues to identify technology gaps that need to be closed in order to enable active orbital debris remediation, and continues to invest in cross-cutting technologies that can enable future implementation of economically feasible active debris removal capabilities. This includes areas such as proximity operations, sensors and instruments, efficient propulsion, guidance and navigation, autonomy, and robotic manipulation. Funding levels vary from year to year depending on solicitation topics, typically ranging from $5-10M in the NASA Space Technology account. A number of enabling technologies are being matured through currently funded projects (e.g., solar electric propulsion, satellite servicing, and many small spacecraft missions).

In addition, NASA is funding research through academia with a primary focus on improving sensors, instruments, and algorithms relative to de-spinning uncooperative debris and controlled deorbit of large objects and exploring potential solutions through small businesses. NASA also invests in promising early-stage concepts and technologies that could alter the landscape for identifying technically and cost-effective, viable orbital debris removal approaches for use by the private sector. For example, NASA routinely attracts new orbital debris removal concepts through its annual NASA Innovative Advanced Concepts (NIAC); Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR); and Space Technology Research, Development, Demonstration, and Infusion (REDDI) solicitations. These solicitations draw participation from a number of commercial entities interested in pursuing this capability as a business venture, with approaches ranging from debris capture through the use of small spacecraft or sails as drag devices. This interest lends itself to the possibility for future public-private partnerships, including prize challenges, and demonstrates potential for commercialization of NASA-developed technologies. The Space Technology Mission Directorate (STMD) continues to monitor activities by commercial entities and international organizations on efforts to advance elements of remediation.

Within the Science Mission Directorate (SMD), the Heliophysics Division (HPD) initiated a cross-cutting strategic activity for basic research and development in the areas of orbital debris measurement and Space Situational Awareness (SSA). As part of this activity, HPD has proactively reached out to a wide set of interagency partners – including the National Oceanic and Atmospheric Administration (NOAA), DoD, and the Intelligence Community (IC) – to identify key experts for engagement, assess the state of the art in orbital debris detection technology, and explore possible mission synergies between the needs NASA and potential partner agencies. SMD is looking forward to engaging with key stakeholders to address this important topic going forward.

6. The Aerospace Safety Advisory Panel stated in its May 2021 meeting that "NASA's move to 'commercial space' has not yet reached the maturity of a purely commercial model." Further, the ASAP stated, "NASA has the accountability for safety but, depending on the acquisition model deployed, does not necessarily have the authority to direct contractor decisions that affect risk posture."

a. How are you handling this situation in which you, as Administrator and NASA have the accountability for safety, yet your managers cannot direct actions or decisions to the contractor to manage risk?

A: For NASA's Commercial Crew Program (CCP), NASA has the ultimate authority to determine whether or not the CCP partners have met NASA's safety and performance requirements, and NASA is actively exercising that authority.

b. To what extent has NASA's role been formally defined, and if so, where?

A: NASA's role is formally defined in CCP Documentation. The primary document is the CCP Program Plan, but roles and responsibilities are captured in other supporting program documentation, as well.

Submitted by Mr. Lamb

1. **Administrator Nelson, this budget request includes more funding *(an increase of $53.8 million, or 12.1%)*, over the FY2021 appropriation for NASA's Lunar Discovery and Exploration Program, which includes Commercial Lunar Payload Delivery Service (CLPS) contracts. In fact, Pittsburgh's own Astrobotic Technology is helping lead the way back to the Moon through a commercial contract with NASA to deliver payloads to the lunar surface for the first time in decades. That mission, among others, will begin the process of building the infrastructure that enables a sustainable presence on the Moon. Can you speak to how American companies like Astrobotic will help prepare for human missions to the moon, and assist NASA in researching and testing technologies?**

A: Fourteen U.S. companies from across the country are part of NASA's Commercial Lunar Payload Delivery Services (CLPS) program. Four of these companies have successfully bid on six task orders to deliver NASA-sponsored U.S. and international payloads to the Moon. These deliveries include scientific instruments to answer basic scientific questions from Decadal Surveys, technology demonstrations, and exploration-enabling payloads that will prepare for human missions to the Moon. CLPS payloads that will prepare the way for human missions include doppler lidar and other navigation demonstrations, several drills and spectrometers to investigate the locations and amount of water and other resources on the lunar surface, and multiple rovers of varying scales. NASA's commercial partners are aiming to provide timely and cost-efficient access to many locations on the Moon through their commercially-derived, innovative landers and technology development. Rapid delivery of so many differing payloads to the Moon will help prepare humans to work more effectively, sustainably, and safely on the lunar surface.

Submitted by Mr. Perlmutter

1. **<u>Space Resources</u> – Utilizing space resources will be key to ensuring sustainable exploration to the Moon and beyond to Mars. Last year, NASA contracted with four commercial companies to buy space resources collected on the lunar surface in support of the Artemis program. In my district, the Colorado School of Mines features the world's first Space Resources graduate program, preparing next-generation of scientists and engineers to engage in this new era of space exploration. Can you please elaborate on the efforts NASA is making to expand investment into space resource extraction and utilization? How can NASA expand its partnerships with universities on space resources?**

A: To expand partnerships with universities, last year, the Space Technology Mission Directorate (STMD) released the new Lunar Surface Technology Research (LuSTR) Opportunities solicitation at the kick-off of the Lunar Surface Innovation Consortium (LSIC). Under the LSIC, an element of NASA's Lunar Surface Innovation Initiative administered by Johns Hopkins Applied Physics Laboratory, teams of experts from academia, industry, and Government are shaping the technologies and systems needed to explore the surface of the Moon in new ways. Over 115 universities, including Colorado School of Mines, participate in LSIC bi-annual meetings, monthly focus groups, and special workshops supporting a cohesive, executable strategy for developing and deploying technologies required for successful lunar surface exploration. LuSTR seeks U.S. universities' ideas to advance technologies needed for sustainable operations on the Moon. In its first year, six awards were made (valued at up to $2M each) to research innovative ways to identify resources, like water, on the Moon, and inventive designs for resource extraction and utilization equipment. This year's LuSTR solicitation was recently released and expands into two topics for excavation and construction: autonomous systems for excavation and site preparation; and systems that can be demonstrated to separate regolith constituents into high-purity elements, minerals, and glasses of interest (e.g., calcium, aluminum, oxygen).

Colorado School of Mines received a number of awards in the area of *in situ* resource utilization, which includes work with small business partner Pioneer Astronautics, Honeybee Robotics, and NASA's Johnson Space Center to build and demonstrate hardware to produce oxygen and steel from lunar regolith. Such technology would provide a foundation for manufacturing operations on the Moon using local resources.

Several Commercial Lunar Payload Services (CLPS) payloads will provide critical information for resource extraction on the Moon, including multiple drills, spectrometers, and rovers to investigate the locations and amount of water and other resources on the lunar surface, a key first step to resource utilization on the lunar surface. The Payloads and Research Investigations on the Surface of the Moon (PRISM) instrument line will solicit proposals annually from the broad community (including universities) to provide instruments for delivery with CLPS that will characterize the lunar environment. These instruments will address high priority science and utilization goals, including water production on the Moon and the behavior of volatile materials that can be used for sustainable activities on the Moon.

2. **<u>Heliophysics</u> – Last year, Congress passed legislation I worked on for over five years to support our nation's space weather enterprise. The PROSWIFT Act helped delineate agency responsibilities, create a new advisory group with the best of the commercial and academic communities, and begin to improve the pipeline between research to operations and operations to research. I'm concerned to review NASA's FY2022 budget request which seeks a decrease in Heliophysics Research and the Living with a Star accounts, including a 60% cut for Space Weather Science and Applications. Can you detail why after Congress passed the PROSWIFT Act NASA decided to reduce its request for this research? Additionally, how is NASA working to effectively implement the PROSWIFT Act both currently and in FY 2022 through this budget**

request?

A: NASA is actively working with other agencies to implement the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act (PROSWIFT) legislation, which has positively impacted the Space Weather enterprise. Full implementation of PROSWIFT will be a multi-year effort that will be implemented in stages.

All of NASA's current and planned Heliophysics missions contribute to a better understanding of the physical processes that drive the space environment around Earth and throughout the solar system, including space weather. The total Heliophysics budget request for FY 2022 is six percent higher than the FY 2021 enacted level, demonstrating NASA's continued commitment to Heliophysics science.

The FY 2022 NASA budget request retains the investment of the FY 2021 enacted budget across all currently funded space weather activities which include:

- The Space Weather Science and Applications project:
  - Continuation of strong support for competed research programs (e.g., Research to Operations to Research [R2O2R], Space Weather Centers of Excellence) to provide critical contributions to the Space Weather enterprise; programs that are developed and selections made with multi-agency input;
  - Sponsoring the maturation of technologies to address current and emerging challenges to space weather research;
  - Selecting four competed CubeSat missions that are directly relevant to enabling improved space weather forecasting;
  - Developing international partnerships to advance technology, shared capabilities, modeling, and data relevant to space weather research; and
- The Heliophysics Environmental and Radiation Measurement Experiment Suite (HERMES) Space Weather measurements at the Gateway.

Furthermore, the Heliophysics Research and Living With a Star (LWS), including Space Weather Science and Applications budget has been modified in part to reflect a transfer content to the newly created Heliophysics Technology line in FY 2022. For example, the FY 2022 budget request transfers $13.7M for Technology Development efforts that are solicited through NASA's annual Research Opportunities in Space and Earth Science (ROSES) solicitation from Heliophysics Research to Heliophysics Technology.

Submitted by Mr. Weber

1. **A lot has happened with China's space program in the past few months. We saw them land a rover on Mars, launch the first elements of their station, and most recently, send 3 astronauts to that station. Additionally, China and Russia have partnered to announce plans for a lunar base. The Chinese Communist Party has also publicly reached out to the international community and invited them to participate in activities onboard their station. I believe this is something the U.S. Congress must look at when ensuring we do not lose these valuable partnerships or encourage the exploitation of these nations wanting to participate in space. When ISS is retired, we need to have U.S. industry leading the way, with their ability to provide cost-effective means of partnership. Do you believe U.S. commercial sector can be a positive enabler and catalyst of U.S. relations with foreign partners moving forward?**

A: The U.S. commercial sector can be a positive enabler and catalyst of U.S. relations with foreign partners going forward. We have already seen several examples of this. NASA's international partners, including Italy, France, and the European Space Agency, are contributing to scientific instruments and technology demonstrations to be delivered to the Moon through the Commercial Lunar Payload Services (CLPS) program. The first private astronaut mission to the International Space Station (ISS), Ax-1, will feature an international crew of American, Israeli, and Canadian spaceflight participants. Also, SpaceX has announced the dearMoon project, which is a lunar tourism mission and art project conceived and financed by a Japanese citizen, Yusaku Maezawa. It will make use of a SpaceX Starship. There have been many positive benefits from our interactions with our ISS International Partners for utilization of the ISS, and NASA intends to extend those relationships to commercial low-Earth orbit (LEO) destinations in parallel with ISS and it is retired.

As we move from LEO to cislunar space, NASA will continue to develop international partnerships advanced through ISS cooperation. For example, the Orion Service Module is a contribution of our European partners, and NASA has entered into agreements with Canadian, European, and Japanese partners to provide important contributions to the lunar Gateway outpost, comprising advanced external robotics, additional habitation, and refueling capability. These partnerships mark a critical part of NASA's efforts to lead an unprecedented global coalition to the Moon, further contributing to the creation of a dynamic and sustainable lunar exploration architecture.

2. **In 2018, Bill Gerstenmaier appeared before the Senate Commerce Committee and stated that "NASA must look beyond ISS in its current form in order to continue U.S. leadership in LEO; that is why the NASA Transition Authorization Act of 2017, together with the Administration, are united in transitioning NASA's LEO activities to a model where NASA is one of many customers of a vibrant, U.S.-led, commercial LEO enterprise. The synergy between industry and Government requirements in this endeavor cannot be overstated. We are partners in ensuring American preeminence as the world's leading spacefaring nation." Do you agree with this statement?**

A: Yes.

3. **NASA must look beyond ISS in its current form in order to continue U.S. leadership in LEO. The reality of aging technology that has well exceeded its predicted lifespan – a true testament of U.S. ingenuity – must be acknowledged and discussed. If the United States wants to avoid a gap in access to LEO, there must be a realistic plan for what comes next. Can you speak on what NASA is doing to ensure no gap exists?**

A: The continuous operation of a research and technology demonstration platform in space is critical to achieving NASA's and the Nation's goals in science, technology, and human spaceflight. As such, NASA is investing resources to foster a robust commercial space economy. NASA seeks to maintain access to a low-Earth orbit (LEO) human-rated platform after the International Space Station (ISS) is retired to continue U.S. human presence and expand the American foothold in space.

In the near-term, NASA is using the ISS and its capabilities to aid in the development of various markets that may lead to non-Governmental demand for commercial LEO destinations. In addition, NASA is pursuing several avenues to facilitate the development of commercial LEO destinations. These include offering the use of an ISS port to a private company to deploy a new commercial element on the ISS, and supporting the development and demonstration of free-flying commercial LEO destinations. NASA's expectation is that one or more of these development and demonstration efforts will prove commercially viable, allowing U.S. and international customers to purchase services in LEO while also providing NASA with the platforms and capabilities it requires in LEO.

Creating a robust LEO economy will be dependent on bringing many new businesses and people into space, and will require the development of not only the supply of services but also the demand for those capabilities. NASA will soon see the first private astronaut mission to the space station. Simultaneously, the Commercial LEO Development and ISS Programs are collaborating to develop and mature the demand side of the LEO economy. NASA is making the ISS available to private entities to conduct activities such as marketing and advertising on board on a fully reimbursable basis. In addition, NASA has issued a preliminary "LEO Demand Forecast," which describes NASA's long-term needs for microgravity services to enable developers of commercial LEO destinations to better define their business case and acquire the necessary capital to develop and deploy their systems.

4. We know that space debris is a problem and this committee held a hearing last congress to discuss possible solutions. China's Long March rocket, recently launched to place parts of its station in space, was not properly de-orbited, and instead experienced an uncontrolled reentry. For days, the world watched one of the largest ever situations of uncontrolled reentry take place, without the ability to accurately predict where it would land until the final hours. Does NASA have as a requirement when contracting with launch providers a de-orbit plan for rocket stages?

A: Safety is a core value at NASA. NASA missions are required to demonstrate compliance with U.S. Government Orbital Debris Mitigation Standard Practices as implemented by NASA directives and technical standards. When contracting with providers, NASA has a requirement that they have a de-orbit plan for rocket stages. Commercial launches (e.g., commercial resupply services, commercial crew) are licensed under and meet Federal Aviation Administration (FAA) and the Federal Communications Commission (FCC) requirements for orbital debris mitigation. For non-NASA contracted launches, NASA would refer you to FAA/FCC. The Agency remains committed to limiting the generation of orbital debris, both by our own missions as well as by promoting safety among all spacefaring entities as described above.

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Submitted by Mr. Obernolte

1. **With the loss of the Arecibo facility in Puerto Rico last fall, and delays to the full operations of the Vera Rubin Observatory, NASA must rely on other facilities to carry out asteroid hunting. How much funding does this budget request for the Goldstone Solar System Radar to conduct NEO survey operations?**

A: The Goldstone Solar System Radar and other planetary radars are not used to conduct Near-Earth Object (NEO) survey operations. Radar is used only to characterize known NEOs that come within radar range, not to discover previously unknown asteroids and comets. The objects must first be discovered and tracked by optical telescopes to provide the pointing and distance information needed so detection by radar can be possible.

NASA Space Communications and Navigation (SCaN) program funds the Goldstone Deep Space Communication Complex within the budget of the Deep Space Network. The Science Mission Directorate's (SMD) Planetary Defense Coordination Office (PDCO) contributes a small amount of operations support for the Goldstone Solar System Radar, managed by the Jet Propulsion Laboratory. The radar returned to full-power (450 kW) operations, after needed repairs, in November 2020.

The FY 2021 budget from PDCO to Goldstone for radar operations support and to JPL for radar observations with Goldstone is $1.4M via PDCO's NEO Observations. The FY 2022 President's Budget Request for NEO Observations enables continued support for Goldstone radar operations and observations at a planned level of $1.5M.

2. **When will NASA complete the required NEO Survey?**

A: The Administration recognizes the importance of NASA's planetary defense efforts and provides in the FY 2022 Budget $143 million – $112 million more than FY 2021 Enacted – for the NEO Surveyor. NASA's NEO Surveyor mission, currently in formulation, has the specific objective of finding 90 percent of undiscovered Potentially Hazardous Asteroids (PHAs) (asteroids greater than 140 meters that can come within approximately five million miles of Earth's orbit) in 10 years. NEO Surveyor would be positioned at the Sun-Earth L1 gravity Lagrange point – where it would have a wider field of observations than from Earth – and would operate in the infrared part of the spectrum, which has the additional advantages of increased sensitivity to the objects as they are heated by the Sun, and enables more accurate characterization of NEO sizes.

The NEO Surveyor mission's Key Decision Point B (KDP-B), the gateway review to Phase B (Preliminary Design), was completed in June 2021. It is estimated that the GEB Survey will be complete approximately ten years after the launch of NEO Surveyor, which is slated to occur in the first half of 2026.

3. **NASA continues to upgrade its Apollo-era Deep Space Network (DSN) system that is critical to communicating with robotic spacecraft and enabling Human exploration. Last year NASA started a DSN "Road to Green" to study the long-term maintenance and upgrade needs to meet future agency needs pursuant to the Inspector General Office's report "NASA's Planetary Science Portfolio." This includes the ongoing DSN Aperture Enhancement Project (DAEP) to expand capacity, improve flexibility, and reduce costs, and augments the 70-meter antennas by completing arrays of four 34-meter Beam Waveguide antennas in California, Space, and Australia by 2026. How is NASA prioritizing these upgrades at the three sites?**

A: NASA recognizes the criticality of adding capacity and capability to the three Deep Space Network (DSN) sites to meet future needs. However, NASA must balance these asset upgrades with the maintenance needs for the entire network. Through the prioritization of long-term maintenance, NASA is ensuring all preventive maintenance is performed, obsolete systems are replaced, and critical information technology security issues are addressed. These priorities are balanced to ensure a robust and resilient communications network that will support all of NASA's future goals.

Submitted by Mr. Gonzalez

1. **Administrator Nelson, as you know, NASA Glenn Research Center in Ohio is critical to propulsion and engine development for not just space, but also our aeronautics industry. I was proud to have led a bipartisan letter this Congress in-support of increased funding towards NASA's Aeronautics and was encouraged to see the FY22 budget request seek a 10% increase to the account. As many of us here are aware, the Chinese are investing heavily in competing with the U.S. and Europe in commercial aviation and aeronautics R&D - of which NASA Aeronautics at Glenn in-particular plays a vital role in ensuring U.S. R&D in aerospace keeps America as the leader in advanced aviation technologies. Given the stakes at play for the U.S. to maintain its edge in aerospace, how is NASA positioning itself with this budget increase to assist the U.S. private sector in staying competitive and also how will NASA Glenn in-particular spearhead these endeavors based on this year's request?**

A: Continued global leadership of the United States aerospace industry is dependent on delivering technically superior, high-quality aircraft that provide high value and return on investment for their customers. Operating efficiency and environmental impact (noise and emissions) have always been critical factors determining the competitiveness of commercial aerospace products. They have taken on increasing importance in light of the economic challenges facing the global airline industry as a result of COVID-19, and the growing urgency of the air transportation industry to reduce their environmental footprint to address community noise and climate change concerns. NASA has a critical role in enabling U.S. industry to maintain its competitive edge through research and development of high-risk, high-return advanced concepts and technologies that will set them apart and ahead of the competition. The large investment in sustainable aviation technologies supported by this budget will enable a suite of critical technologies to be matured by 2025-2028 to a technical readiness level such that industry can make decisions about further developing and commercializing them for vehicles entering into service in the early 2030s. With other governments around the world right now spending billions of dollars investing in "green aviation" technology development with foreign manufacturers, NASA investments help to maintain a level playing field and enable U.S. industry to remain economically competitive.

The NASA's FY 2022 budget enables Glenn Research Center (GRC) to continue development of cutting-edge technologies and utilization of their world-class facilities and expert staff in the areas of aeronautics, aerospace, and space. GRC is leading the advancement of technologies and concepts for electric and hybrid aircraft propulsion systems. The impact of NASA GRC's research will be reduced aviation emissions and a better trade balance in the aviation sector as a result of technology transfer to U.S. companies. GRC will continue the development of systems and components utilizing unique world-class researchers and facilities to create and demonstrate the enabling technologies for hybrid single-aisle aircraft, electric regional aircraft, and smaller Advanced Air Mobility (AAM) personal air mobility vehicles.

GRC researchers have played a key part in the creation of the electrical systems technology and aircraft conceptual design that have led to substantial industry investments in hybrid and electric aircraft. Aircraft concepts have included electric and hybrid low- and zero-emissions systems and advanced airframe / propulsion configurations that have influenced world-wide thinking in this area. GRC has demonstrated first-in-the-world power system components that are around three times lighter and more efficient than prior technology, as well as enabling material technologies.

The GRC NASA Electric Aircraft Testbed (NEAT), the only test bed where full-scale megawatt (MW)-class electrified power train systems can be tested at altitude, enables critical test and validation of the most viable concepts as a means to prepare for flight demonstrations. NEAT will continue to expand capability and serve as the state-of-the-art full-scale MW testbed for both industry partnership testing and in-house NASA research efforts to further mature electric aircraft technologies.

NASA will rely on GRC facilities and laboratories, and talented workforce, to explore new concepts for improving electric propulsion system component reliability and safety that will inform future standards

development for electric vertical takeoff and landing (eVTOL) vehicles and the development of the next-generation small-core turbofan engine technologies that will enable hybrid-electric propulsion systems.

2. Administrator Nelson, Does NASA have an office or audit function to review start-up companies that are seeking to raise money quickly from funds that may come from foreign sources? If not, do you believe this represents a potential concern that needs to be addressed?

A: This function is appropriately handled by the Committee on Foreign Investment in the United States (CFIUS), the interagency committee authorized to review foreign investments in U.S. companies to determine the effect on U.S. national security. The Department of Treasury refers certain cases to NASA for review, as appropriate. NASA complies with requirements in law and policy concerning U.S. ownership of the companies with which we establish contracts and agreements. These requirements are primarily contained within Federal Acquisition Regulation (FAR) Part 25 and the accompanying NASA Federal Acquisition Regulation Supplement (NFS) 1825. NASA's acquisition workforce acquires domestic end products to the maximum extent practicable and uses the exceptions available in the current FAR Subsection 25.103, when necessary, to support the Agency's mission under various programs and projects. NASA is supporting the Office of Management and Budget (OMB) Made In America Office which was established via Executive Order (EO) 14005 to identify improvements to these requirements to ensure the continued safeguarding of U.S. interests for NASA contracts and agreements.

3. Administrator Nelson, in general, does NASA have all the legal authorities necessary to prevent the theft and unauthorized access of space technology developed with or in partnership with NASA funding? As this committee considers the upcoming NASA Authorization Act, are there additional enforcement authorities or mechanisms that may be helpful for us to consider to ensure you can prevent the loss of critical IP with commercial partners and academia?

A: NASA currently has sufficient legal authorities necessary to prevent the theft and unauthorized access to space (and other NASA) technology developed with or in partnership with NASA funding (e.g., 18 U.S.C. 641).

4. Administrator Nelson, does the Aeronautics Mission Directorate track funding levels and stimulus initiatives from China, the EU, and its member states on sustainable aviation initiatives to ensure the U.S. industry maintains its competitive edge?

A: NASA maintains awareness of aeronautics research activities and associated funding by counterpart agencies in other countries through many means, including engagement in professional and technical societies, researcher and institutional technical exchanges, technical research publications and studies, as well as leveraging various U.S. Government and private sector information sources and reports. NASA technical subject matter experts maintain world-class expertise in understanding and advancing the state of the art in their technical disciplines, including understanding advances made in other countries. NASA's Aeronautics Research Mission Directorate (ARMD) participates in information exchanges on research activities with counterpart agencies through the International Forum for Aviation Research, including a focused working group effort related to sustainable aviation. NASA also conducts limited collaborative research with foreign counterpart agencies on non-competitive topics of mutual benefit, such as safety technologies and fundamental tools and methods. Through all of these mechanisms, NASA technical experts are able to maintain situational awareness of foreign government initiatives to inform our internal decisions and support the competitive position of U.S industry.

5. Administrator Nelson, the Chinese have publicly reached out to the international community and invited them to participate in activities onboard their new space station. I believe this is

something the U.S. Congress must look at when ensuring we do not lose valuable partnerships or encourage the exploitation of nations wanting to participate in space. When the International Space Station (ISS) is retired, we need to have U.S. industry leading the way, with their ability to provide cost-effective means of partnership. Do you believe U.S. commercial sector can be a positive enabler and catalyst of U.S. relations with foreign partners moving forward?

A: The U.S. commercial sector can be a positive enabler and catalyst of U.S. relations with foreign partners going forward. We have already seen several examples of this. NASA's international partners, including Italy, France, and the European Space Agency, are contributing to scientific instruments and technology demonstrations to be delivered to the Moon through the Commercial Lunar Payload Services (CLPS) program. The first private astronaut mission to the International Space Station (ISS), Ax-1, will feature an international crew of American, Israeli, and Canadian spaceflight participants. Also, SpaceX has announced the dearMoon project, which is a lunar tourism mission and art project conceived and financed by a Japanese citizen, Yusaku Maezawa. It will make use of a SpaceX Starship. There have been many positive benefits from our interactions with our ISS International Partners for utilization of the ISS, and NASA intends to extend those relationships to commercial low-Earth orbit (LEO) destinations in parallel ISS and after it is retired.

As we move from LEO to cislunar space, NASA will continue to develop international partnerships advanced through ISS cooperation. For example, the Orion Service Module is a contribution of our European partners, and NASA has entered into agreements with Canadian, European, and Japanese partners to provide important contributions to the lunar Gateway outpost, comprising advanced external robotics, additional habitation, and refueling capability. These partnerships mark a critical part in NASA's efforts to lead an unprecedented global coalition to the Moon, further contributing to the creation of a dynamic and sustainable lunar exploration architecture.

6. Administrator Nelson, looking to ensure that the U.S. avoids a gap in access to LEO, there must be a realistic plan for what comes next after ISS. Can you speak on what NASA is doing with this budget request to ensure no gap exists?

A: The continuous operation of a research and technology demonstration platform in space is critical to achieving NASA's and the Nation's goals in science, technology, and human spaceflight. As such, NASA is investing resources to foster a robust commercial space economy. NASA seeks to maintain access to a low-Earth orbit (LEO) human-rated platform after the International Space Station (ISS) retires to continue U.S. human presence and expand the American foothold in space.

In the near-term, NASA is using the ISS and its capabilities to aid in the development of various markets that may lead to non-Governmental demand for commercial LEO destinations. In addition, NASA is pursuing several avenues to facilitate the development of commercial LEO destinations. These include offering the use of an ISS port to a private company to deploy a new commercial element on the ISS, and supporting the development and demonstration of free-flying commercial LEO destinations. NASA's expectation is that one or more of these development and demonstration efforts will prove commercially viable, allowing U.S. and international customers to purchase services in LEO while also providing NASA with the platforms and capabilities it requires in LEO.

Creating a robust LEO economy will be dependent on bringing many new businesses and people into space, and will require the development of not only the supply of services but also the demand for those capabilities. NASA will soon see the first private astronaut mission to the space station. Simultaneously, the Commercial LEO Development and ISS Programs are collaborating to develop and mature the demand side of the LEO economy. NASA is making the ISS available to private entities to conduct activities such as marketing and advertising on board on a fully reimbursable basis. In addition, NASA has issued a preliminary "LEO Demand Forecast," which describes NASA's long-term needs for microgravity services to enable developers of commercial LEO destinations to better define their business case and acquire the necessary capital to develop and deploy their systems.

7. Administrator Nelson, will an updated ISS transition plan be produced by the agency under your leadership and if so, when can we expect that and how will it differ from what Congress saw previously? Can Congress be assured that the plan will indeed include actual transition elements?

A: NASA will submit an updated International Space Station (ISS) Transition Plan in early 2022, and will detail the elements of ISS transition that NASA is planning for, including NASA and non-NASA research, crew, vehicle lifetime, international partnerships, and commercial marketplace and other transition timeline indicators.

8. Administrator Nelson, how will the Aeronautics Mission Directorate work to advance sustainability goals and competitiveness of the U.S. aviation industry through its R&D programs under the Biden Administration?

A: With NASA's FY 2022 budget, NASA is leading four transformations of the global aerospace industry for sustainability, greater mobility, and economic growth. These transformations will support the competitiveness of the U.S. aviation industry, including traditional manufacturers and suppliers as well as new market entrants.

NASA Aeronautics is partnering with industry, academia, and other agencies through the Sustainable Flight National Partnership (SFNP) to accomplish the aviation community's aggressive international carbon reduction goals. Through our collective work in three areas – advanced vehicle technologies, efficient airline operations, and sustainable aviation fuels – we aim to reduce carbon emissions from aviation by half by 2050, compared to 2005, and potentially achieve net-zero emissions by 2060.

SFNP is a focused set of major technology demonstrations by NASA Aeronautics and industry including a first-ever high-power megawatt-class electrified powertrain for large transport aircraft propulsion, ultra-high efficiency long and slender wings, advanced composite structures produced four to six times faster than the current state of the art, and advanced small-core engine technologies based on breakthrough NASA innovation.

The iconic centerpiece of NASA's SFNP will be a full-scale technology demonstrator X-plane, or Sustainable Flight Demonstrator (SFD), built to test an ultra-efficient aerodynamic design and possibly other new technologies, and retire technical risks, to solve the challenges of integrating those technologies and prove their predicted benefits in flight. NASA expects to issue risk reduction contracts this summer (2021) to continue maturing some of the most promising design concepts. NASA plans to solicit industry in early 2022 for preliminary designs of aircraft configurations that could be tested and potential associated technologies, with the potential for first flight of the demonstrator in late 2026.

Second, NASA is supporting connection of the world through high-speed commercial flight by removing barriers to commercial supersonic flight over land by proving that we can get rid of the sonic boom, tackling the next challenges in local noise and emissions, and investigating the potential of even higher speed flight.

Third, through research in new technology areas such as Advanced Air Mobility, Unmanned Aircraft Systems, and use of electric Vertical Takeoff and Landing, NASA is supporting the transformation of the way people and goods move through aviation. NASA is rallying emerging markets to tackle the challenges of creating an air transportation system featuring all-electric, autonomous, efficient, and safe systems operating over the most rural countryside to the densest, skyscraper-filled urban environment.

Fourth, NASA is supporting transformation of the efficiency and safety of the entire global aviation system through future airspace tools and system design that supports all of these users.

NASA is exploring the underlying concepts, tools and technologies that will enable the future transformation of the global aviation system, and engaging and inspiring future generations of diverse scientists and engineers who will lead the Nation to a zero-carbon emissions aviation future vision. These activities will support the continued technical leadership and economic competitiveness of the U.S. aerospace industry and support high-skill, high-wage jobs across the country.

9. Administrator Nelson, are funding levels for programs, such as the Hybrid Thermally Efficient Core (HyTEC) and Electrified Powertrain Flight Demonstration (EPFD), adequate to accelerate the deployment of next generation propulsion and aircraft technologies?

A: NASA's Electrified Powertrain Flight Demonstration (EPFD) and Hybrid Thermally Efficient Core (HyTEC) projects accelerate the deployment of technologies that could lead to potentially transformative solutions that improve the environmental sustainability and economic impact of next-generation subsonic transport vehicles.

The EPFD project focuses on integrated electrified aircraft propulsion (EAP) concepts. To turn the promise of EAP into reality, the EPFD project is establishing flight demonstration partnerships with U.S. industry that will mature integrated megawatt-class EAP powertrain systems and enable their deployment in commercial products by 2035 or sooner. EPFD's budget will allow partnerships with at least one company for single-aisle applications meeting the current project objectives.

The HyTEC project focuses on accelerating a suite of small-core propulsion technologies into next-generation engines to dramatically reduce fuel burn and associated emissions and to provide high levels of electrical power extraction to enable hybrid-electric propulsion systems. The funding levels requested in the President's FY 2022 budget support the partnerships with U.S. industry to develop the technologies required to meet the project objectives.

10. Administrator Nelson, in addition to space technology, the Chinese are investing heavily in competing with the U.S. and Europe in commercial aviation and aeronautics R&D - of which NASA Aeronautics at Glenn and other centers play a critical role in ensuring U.S. R&D in aeronautics technologies keeps the U.S. as the leader in advanced aviation technologies. I was encouraged to see your FY22 Budget Request seek a 10% increase to NASA Aeronautics to continue to invest in these critical technologies, including the new Sustainable Flight Demonstrator that will new aircraft structures, advanced composites and new propulsion technologies to increase efficiency and reduce noise. Can you provide an overview of this new X-Plane and its development, which will follow the successful development of your recent electric and supersonic X-Planes that are nearing their first flights?

A: The SFD project is focused on demonstrating critical subsonic transport vehicle technologies in a relevant flight environment. The purpose of the project is to identify and rapidly mature critical technologies that have a high probability of transition to the global commercial transport fleet by the early to mid-2030s.

In October of 2020, NASA Aeronautics established a team of seasoned technical subject matter experts, acquisition experts, and project development personnel to lead the FY 2022 start-up of this project. The team is utilizing established Agency processes used by recent supersonic and electric projects to rapidly develop and mature technical, cost, schedule, and risk plans for the SFD.

In December of 2020, in support of the development of the acquisition strategy for the SFD project, the team released a request for information to U.S. industry to help identify technologies that have a high probability of transition to the U.S. commercial transport fleet. A robust and diverse response from U.S. industry airframers and engine companies was obtained. The team found that several U.S. industry responses are aligned with the goals of increased efficiency and reduced community noise for the next generation of subsonic commercial

transports. Given the promising responses from U.S. industry, in May 2021, the team released a competitive procurement to jump start U.S. industry risk reduction efforts. The team is preparing another competitive procurement action for June 2022 to down-select the SFD demonstrator, aiming at first flight in 2026.

11. Administrator Nelson, based on your understanding of China's investment in Aeronautics R&D, are these new X-Planes enough to keep the U.S. as the global leader in advanced aviation technologies, or are there additional programs and technologies that this Committee should be looking at to ensure our continued leadership in this sector?

A: China is undertaking an aggressive research portfolio across a wide range of aerospace sectors, and will be a growing global competitor as they mature products and bring them to market. NASA's FY 2022 budget supports a robust, balanced portfolio of aeronautics research and development activities that are intended to bolster continued U.S. leadership in the global aerospace industry through superior technologies and products. NASA research, simulations, and ground and flight demonstrations are directly supporting transformations in four key areas – ultra-efficient commercial aircraft, high-speed flight, advanced air mobility, and the next evolution of air traffic management. The proposed SFD and the complementary technology advances that make up the SFNP will enable entry into service in the early 2030s of next-generation single-aisle aircraft that are at least 25 percent more fuel efficient than those of today. The X-59 flight campaigns will inform global and U.S. rule changes to allow supersonic flight over land, positioning U.S. manufacturers to develop and produce quiet supersonic aircraft for sale and operation around the world. NASA research, test capabilities and partnership with the Department of Defense (DoD) continue to advance the state of the art in hypersonics across a range of use cases. Research encompassing the all-electric X-57 and a wide range of technologies and operational concepts needed to support the Advanced Air Mobility market will support the pioneering leadership of U.S. industry in a market with an annual estimated value of $115 billion by 2035. NASA believes this comprehensive portfolio is well positioned to support continued U.S. leadership.

12. Dr. Zurburchen, the head of the Science Mission Directorate, has spoken extensively about how innovations in small satellites and small launch are transforming the agency's ability to get more science returns per dollar, making the most of resources from the American people and Congress, while enhancing benefits to life on Earth. Administrator Nelson, can you speak to how you will continue and advance these trends in small launch and small satellites?

A: NASA, working closely with industry, has advanced new ways to deliver small payloads to orbit and deep space over the past decade. We have used a variety of innovative approaches and tools such as rideshares, propulsive secondary payload adapters, and hosted payloads on commercial satellites, in addition to dedicated small launch vehicles.

NASA's CubeSat Launch Initiative (CSLI) has deployed over 118 missions in space from over 111 unique organizations, representing 43 states, Puerto Rico, and the District of Columbia. A total of 202 CubeSat missions have been selected, with more than 50 CubeSats currently manifested for launch.

The Science Mission Directorate (SMD) has successfully sponsored and launched 30 SmallSat and CubeSat missions in the last 11 years. Currently, an additional 44 SmallSat missions are in development, spanning all five of SMD's science divisions (Astrophysics, Biological and Physical Sciences, Earth Science, Heliophysics, and Planetary Science).

In addition, NASA is implementing an innovative new competitive process to procure launch services so they are readily available to more of NASA's SmallSat missions. The new Venture-Class Acquisitions of Dedicated and Rideshare (VADR) launch services Indefinite Delivery Indefinite Quantity (IDIQ) contract is designed specifically to meet the requirements of smaller payloads that are risk-tolerant but also have unique orbital, inclination, and schedule requirements. Four SMD SmallSat missions in development are planning to use the upcoming VADR IDIQ contract.

13. Administrator Nelson, market studies have indicated that autonomous manufacturing and other uncrewed activities have as significant a growth potential for the LEO economy as human spaceflight, if not more so. How does NASA plan to foster and utilize uncrewed LEO activities in the Commercial LEO Development Program, while balancing its requirements to continue human presence in LEO?

A: NASA is working toward the development of commercial markets and demand for low-Earth orbit activities beyond the more "traditional" microgravity research and applications into broad sectors of the economy. Unless this demand is expanded, future private low-Earth orbit platforms will have difficulty closing their business cases. Thus, NASA has identified several initial potential high-payoff market areas, and has increased the focus and resources toward projects in these areas, including protein crystallization, industrial biomedicine, and in space production/manufacturing.

14. Administrator Nelson, In addition to serving as a platform for access to the Lunar surface, the Gateway in cislunar space is the staging spot for NASA's Marstransportation systems that will be necessary to send the first crews on Mars fly-by missions as early as 2033 and Mars surface missions later in the decade. How is NASA designing the Gateway so it can leverage the capabilities of the Space Launch System exploration rocket and Orion spacecraft to stage the necessary systems for future Mars missions? Is this a platform that we can continue to grow over the decade to ensure that America continues pushing on to Mars and doesn't stop with Lunar surface missions?

A: Gateway is situated in an orbit that allows access by the Space Launch System (SLS) and Orion for crew delivery for both lunar systems and potentially as a Mars staging point. This unique lunar orbit also allows for low-energy transfer orbits for cargo delivery from Earth and is reachable by other launch vehicles (of which several are available on the market today). Gateway is a platform that will be built around NASA's two elements, the Power and Propulsion Element and the Habitation and Logistics Outpost, and which will be expanded beyond these two elements with contributions from international partners. This build-up is facilitated by a reliance on internationally agreed-to deep space interoperability standards. The international partner contributions will enable longer-duration crew stays, logistics resupply, new science and technology demonstrations, and support systems for maintenance and platform longevity. It is important to note that while an orbit like the one Gateway will use could potentially be used as a Mars mission staging point, decisions on this and on many other technical aspects of a Mars mission architecture (for example, whether there will be a fly-by mission at all) are still open, with final decisions to be made at some point in the future.

15. Administrator Nelson, how does NASA's FY2022 budget seek to fully utilize the capabilities and resources of NASA Glenn Research Center? With electrified aircraft being a higher priority for NASA now, what role will Glenn Research Center play to carry out this endeavor?

A: NASA Glenn Research Center (GRC) has been a vital contributor to NASA's missions, on Earth, near Earth, and in deep space. The NASA's FY 2022 budget enables Glenn Research Center to continue development of cutting-edge technologies and utilization of their world-class facilities and expert staff in the areas of aeronautics, aerospace, and space.

- Leading the development of the Power and Propulsion Element (PPE), the first element to be launched as part of Gateway, NASA's orbiting lunar outpost. The PPE will demonstrate the use of solar-electric propulsion to maneuver and provide power to the Gateway. See:
    - https://www.nasa.gov/feature/glenn/2021/we-are-fired-up-gateway-propulsion-system-passes-first-test
    - https://www.nasa.gov/gateway

- Mission design, analysis, and technology maturation of fission surface power, advanced solar electric propulsion, and cryogenic fluid management technologies for future deep space exploration missions. See:
  - https://www.nasa.gov/mission_pages/tdm/fission-surface-power/index.html
  - https://www.nasa.gov/mission_pages/tdm/sep/index.html

- Leading the formulation of the Communication Services Project, an effort to enable commercial communications providers for near-Earth operations. See:
  - https://www.nasa.gov/directorates/heo/scan/services/demonstrating_a_space_comm_universal_translator

- Supporting NASA's strategic vision for aeronautics by leading the development of hybrid-electric propulsion systems, which will reduce fuel consumption, noise, and emissions and enable the U.S. aviation industry to maintain global leadership. See:
  - https://www1.grc.nasa.gov/aeronautics/eap/

- Leading high-temperature materials research and continuing to conduct hypersonic propulsion system-level research, design, and ground testing. Strengthening and expanding the partnership between NASA and the Department of Defense (DoD), and the opportunity to explore collaborations with academia and industry to ensure U.S. supremacy in hypersonics.

- Inspiring the next generation of scientists, technologists, engineers, mathematicians, and explorers by supporting the Agency's STEM engagement efforts, as well as driving economic growth through our Small Business Innovation Research and Technology Transfer programs. See:
  - https://www.nasa.gov/centers/glenn/stem
  - https://www1.grc.nasa.gov/space/scan/acs/tech-studies/sbir/#:~:text=The%20Small%20Business%20Innovation%20Research,develop%20federally%20funded%20R%26D%20projects.
  - https://technology.grc.nasa.gov/

- Sustaining our staffing and maintaining our world-class test facilities, including NASA's Neil A. Armstrong Test Facility in Sandusky, Ohio, where we expose spacecraft to the extreme environments of space. See:
  - https://www.nasa.gov/centers/glenn/about/testfacilities/index.html

GRC is leading the advancement of technologies and concepts for electric and hybrid aircraft propulsion systems. The impact of NASA GRC's research will be reduced aviation emissions and a better trade balance in the aviation sector as a result of technology transfer to U.S. companies. GRC will continue the development of systems and components utilizing unique world-class researchers and facilities to create and demonstrate the enabling technologies for hybrid single-aisle aircraft, electric regional aircraft, and smaller Advanced Air Mobility (AAM) personal air mobility vehicles.

GRC researchers have played a key part in the creation of the electrical systems technology and aircraft conceptual design that have led to substantial industry investments in hybrid and electric aircraft. Aircraft concepts have included electric and hybrid low- and zero-emissions systems and advanced airframe / propulsion configurations that have influenced worldwide thinking in this area. NASA Glenn has demonstrated first-in-the-world power system components that are around three times lighter and more efficient than prior technology, as well as enabling material technologies.

The GRC NASA Electric Aircraft Testbed (NEAT), the only test bed where full-scale megawatt (MW)-class electrified power train systems can be tested at altitude, enables critical test and validation of the most viable concepts as a means to prepare for flight demonstrations. NEAT will continue to expand capability and serve as the state-of-the art full-scale MW testbed for both industry partnership testing and in-house NASA research

efforts to further mature electric aircraft technologies.

NASA will rely on GRC facilities and laboratories, and talented workforce, to explore new concepts for improving electric propulsion system component reliability and safety that will inform future standards development for electric vertical takeoff and landing (eVTOL) vehicles and the development of the next-generation small-core turbofan engine technologies that will enable hybrid-electric propulsion systems.

16. Administrator Nelson, how is NASA making the judgment call between the viability of Nuclear Electric Propulsion (NEP) vs Nuclear Thermal Propulsion (NTP) when it comes to our eventually journey to Mars within the next two decades?

A: Advancing an in-space nuclear propulsion capability potentially has strategic importance for future NASA exploration capabilities. There are engineering differences between Nuclear Electric Propulsion (NEP) and Nuclear Thermal Propulsion (NTP) systems that drive different technology development requirements where both are at a low technology readiness level. In FY 2020, NASA's Space Technology Mission Directorate requested the National Academies of Sciences, Engineering, and Medicine to convene an *ad hoc* committee to identify primary technical and programmatic challenges, merits, and risks for developing and demonstrating NTP and NEP technologies of interest to future exploration missions. This and other independent studies of NEP and NTP recommend further research and development in both systems to reduce the risk of selecting a single propulsion system before hardware development needs are better known. NASA desires to work with Congress in crafting a balanced nuclear program within NASA that supports critically important Agency decisions and the emerging National strategy for space nuclear systems.

17. Administrator Nelson, how is NASA's work with the Department of Defense in-regards to hypersonics development reflected in this budget request?

A: NASA subject matter experts (SMEs) directly participate in DoD activities such as the Hypersonic Airbreathing Weapon Concept (HAWC) program, Tactical Boost Glide (TBG) program, and the Advanced Full Range Engine (AFRE) program. In exchange for the NASA SMEs contributing to the DoD's mission success, NASA receives ground and flight data from testing that would not be obtainable on NASA's budget alone. This data is used to improve NASA's modeling capability for future applications. Labor costs for NASA SMEs are covered in the budget proposal.

Civil servant labor is also budgeted for coordination and collaboration activities, such as those occurring with DoD's Principal Director for Hypersonics office and with the Joint Hypersonics Transition Office (JHTO).

NASA-directed hypersonics research indirectly supports DoD more broadly. The majority of NASA research in systems analysis; propulsion technologies; vehicle technologies; and high temperature, durable materials can be applied to civil- or defense-related applications. This NASA-directed portfolio of research is informed by regular interaction with DoD partners on Science and Technology (S&T) investment.

18. Administrator Nelson, does the FY2022 budget request adequately fund Fission Surface Power development, to ensure that the technology is ready to go ahead of any lunar surface endeavors within the current Artemis timeline?

A: NASA's objective is to demonstrate an integrated fission power system on the lunar surface across an operational spectrum that verifies full functionality and power performance to support human exploration goals. NASA considers this technology its highest nuclear system priority.

NASA's strategy to establish a nuclear surface power capability requires collaboration with the Department of Energy and a planned reliance on the Nation's commercial nuclear industry. The FY 2022 budget request

fully supports the execution of this strategy and will provide up to three early stage designs from industry. This initial design effort is needed to align NASA's goals with industry capabilities and inform the scope, cost, and accelerated timeline for a fission surface power system. These requested funds will also allow NASA to advance space-rated power conversion systems, and mature high-risk reactor technologies on low-enriched uranium moderator materials and lighter weight radiation shielding.

19. Administrator Nelson, NASA has been developing nuclear thermal propulsion technologies for several years and recently the Defense Advanced Research Projects Agency (DARPA) announced that they will be developing an NTP system called Demonstration Rocket for Agile Cislunar Operations (DRACO) which will launched in 2025. How is NASA collaborating with DARPA on the DRACO program in the development of NTP technologies and what is NASA doing in identifying the synergies between a future human mission to Mars and future defense applications for NTP?

A: NASA is collaborating with the Defense Advanced Research Projects Agency (DARPA) Demonstration Rocket for Agile Cislunar Operations (DRACO) program to identify shared technology interests and outline specific roles and responsibilities for developing the technical foundations and capabilities needed to address key NTP technical challenges. The goal of the DARPA DRACO program is to execute a mid-2020s NTP flight demonstration that is representative of a high-thrust system needed for national security cislunar operations. An in-space NTP flight demonstration may provide valuable knowledge in the areas of launch safety design and operations, propellant management, and remote engine operation and control for future NASA Mars exploration and separate Department of Defense (DoD) cislunar missions. Resolving the technical challenges and exploring in-space performance capability is mutually beneficial to both NASA and DARPA for our distinct civil and defense missions, and both organizations are working together to formulate collaboration plans for the DRACO program. DARPA DRACO currently has industry performers on contract for Phase 1 efforts, which seek to establish the preliminary design of a near-term engine and vehicle stage. NASA currently is providing subject matter expertise, test facility, and cryogenic fluid management support to DARPA's Phase 1 effort. NASA also is exploring future partnering opportunities as the DRACO mission evolves.

20. Administrator Nelson, in March of 2018, NASA successfully demonstrated a 10 kilowatt nuclear reactor using highly enriched uranium (HEU) called KRUSTY. Building on the successful of this program, NASA requested $34M in FY22 to start the fission surface power (FSP) program at Glenn Research Center and plans to release a RFP this year. Is NASA considering using HEU for FSP or are they requiring the use of low enriched uranium (LEU)? Also, will federal labs and FFRDC be excluded from competing with industry in the development of a FSP system?

A: NASA and the Department of Energy (DOE) conducted an experiment in early 2018 to demonstrate a one-kilowatt nuclear reactor power generation system using a highly enriched uranium fuel core. The Kilopower Reactor Using Stirling Technology (KRUSTY) experiment showed the engineering feasibility of a 1-kilowatt Government reference design and demonstrated its performance under both normal and off-normal conditions. A fission reactor study completed in March 2020 found that low-enriched uranium (LEU) reactor solutions can be designed to have roughly the same weight as the high-enriched (HEU) Government reference design demonstrated by the KRUSTY experiment. NASA and DOE are now working together to issue a request for proposal to industry for preliminary designs of an integrated fission surface power system, with plans to award up to three industry contracts for preliminary designs of a 10-kilowatt-electric-class fission power system. The industry awards will have a one-year performance period, and the results will inform NASA design and performance requirements for a lunar demonstration. While NASA sees the benefit of a low-enriched reactor system, particularly in the areas of enhanced industry participation and reduced security requirements, preliminary designs intending to use highly-enriched uranium will not be expressly precluded. Industry proposers will have to demonstrate that "the mission would not be viable with other nuclear fuels or non-nuclear power sources" consistent with current policies that strongly emphasize the use of low enriched uranium over highly enriched uranium. The solicitation specifically targets industry-led design solutions.

While Federally Funded Research and Development Centers (FFRDCs) and Federal labs are not eligible to propose or participate as teaming partners on a proposal, industry proposals can identify work scope where they would like FFRDC or Federal support.

21. Administrator Nelson, during FY 22, of the $390 million proposed for Construction and Environmental Compliance and Restoration, what is the agencies estimate for facilities and construction projects the agency plans to allocate to NASA Glenn Research Center and Plumbrook?

A: Within the Fiscal Year (FY) 2022 Construction and Environmental Compliance and Restoration (CECR) request, NASA plans to allocate $20 million for Construction of Facilities (CoF) projects at the Glenn Research Center (GRC). These include phased repairs to GRC's storm sewer system and to the electrical distribution system at GRC to increase safety and reliability. NASA's CoF request also includes funding to upgrade the energy monitoring and control system at GRC.

22. Administrator Nelson, for the FY 2021 operating plan, how much funding has the agency allocated in the Construction and Environmental Compliance and Restoration Line item for NASA Glenn Research Center? Please provide a list of the "horizontal infrastructure" or maintenance projects that the agency has deferred due to the insufficient appropriation?

A: In FY 2021, NASA funded $25.0 million at GRC for three CoF projects, including the "Repair Cooling Tower Nos. 3 & 6 Water Distribution System" project, the "Repair Steam Distribution System, Phase 4" project, and the "Repair Electrical Distribution Systems, Phase 3 of 5" project.

For FY 2021, the CECR budget request was $539.1 million, of which $464.4 million was allocated for CoF and $74.7 million was allocated for Environmental Compliance and Restoration (ECR). NASA's enacted appropriation for CECR was $110.6 million below the request. Across the Agency, a total of eight planned construction projects were deferred as a result of funding levels below budget request. These include the "Repair Facility Horizontal Communications Infrastructure" project at the Neil A. Armstrong Test Facility (formerly Plum Brook Station), intended to correct limitations of existing legacy cabling. The complete list of all planned CoF projects deferred in FY 2021 includes:

- Engineering and Mission Operations Facility (new construction building, Ames Research Center [ARC]);
- Restore Reliability of Vertical Motion Simulator (technical capability, ARC);
- Repair Center-wide Building Envelopes (construction repair, Armstrong Flight Research Center [AFRC]);
- Repair Facility Horizontal Communications Infrastructure (horizontal infrastructure, GRC/Armstrong Test Facility [ATF]);
- Center wide Fire Alarm Upgrade (horizontal infrastructure, Goddard Space Flight Center [GSFC]);
- Compressor Station Upgrades, Phase 3 of 4 (horizontal infrastructure, Langley Research Center [LaRC]);
- Utility Tunnels 1 & 2 Repairs, Phase 1 (horizontal infrastructure, LaRC); and
- Repairs to Critical Test Complex Power Generation System (technical capability Stennis Space Center [SSC]).

23. Administrator Nelson, what are some of the consequences for deferring the maintenance projects that NASA was unable to complete in at NASA Glenn Research Center or Plumbrook during FY 2021?

A: NASA's current deferred maintenance (DM) backlog is valued at $2.6 billion and continues to grow. Of that, the DM backlog at GRC is $244.7 million. In FY 2021, deferral of repairs to horizontal communications at GRC/ATF, noted above, means that necessary upgrades to information technology (IT) infrastructure and building automation and control systems, which depend upon the planned cabling improvements, may also be delayed.

Submitted by Ms. Stevens

1. **Administrator Nelson, a Majority staff report issued by this Committee in March of this year found that, within NASA's own STEM workforce, male employees outnumbered female employees by a 3-to-1 ratio, and white employees similarly outnumbered racial and ethnic minority employees by 3-to-1 as well. Both ratios were significantly higher for the STEM workforce alone than for the agency workforce as a whole. Why does NASA have that disparity in the STEM workforce, and why has it persisted for decades?**

A: First, I want to thank the committee for their work on this important issue. I am committed to ensuring diversity, equity, inclusion, and access (DEI&A) throughout NASA. NASA missions are incredibly challenging, and we must engage with every corner of this nation to realize these bold goals. I am committed to ensuring that the NASA workforce and its leadership reflects America. For the first time ever, NASA has a senior advisor for DEI&A and our FY 2022 budget requests increased resources for DEI&A. NASA's Office of Diversity and Equal Opportunity received a $5 million plus-up in the FY 2022 budget request. With that funding, NASA will be able to significantly enhance its service levels for Diversity, Equity, and Inclusion (DEI), including for: (1) engaging underserved communities and improving equity in NASA's administration of grants to external institutions that conduct science, technology, engineering, and mathematics (STEM) research (e.g., colleges and universities); (2) improving DEI data/analytics capabilities; and (3) implementing the President's new Executive Orders and Memoranda on DEI.

NASA employees – regardless of age, gender, and racial backgrounds – cite shared values, commitment to the mission and loyalty to NASA as key reasons why they feel positively about their jobs and why they stay at NASA. However, this low attrition rate also means NASA has had fewer opportunities to bring onboard new hires in the past to diversify our workforce. At NASA, we have many women and people of color serving key leadership positions, and we are focused on putting the first female and person of color on the Moon. Additionally, over the past five years, the percentage of females in Science and Engineering disciplines within NASA has increased by two percent. That said, we are continually seeking new ways to increase diversity in our ranks, whether that be diversity in terms of age, experience, gender, race, social background or even ways to problem solving.

NASA senior leaders are working on a multi-year, overarching strategy that will provide more agility across our overall workforce, including increased talent mobility and investment in non-permanent civil service appointments to support shorter-duration projects and projects where required skills and knowledge change rapidly. Additionally, we are looking at new ways of bringing on new talent to the Agency. In particular, NASA's Office of Human Capital has implemented several new tools that Centers and Mission Support Enterprise Offices are using to aid them as they create the workforce that is efficiently shaped and sized to meet the needs of the future. These tools include:

- Enhanced hiring flexibilities including direct hire authority, which provides greater reach to external talent and faster time to hire;
- Talent Marketplace – an internal application where detail and lateral opportunities are shared with the workforce; and
- Increased use of rotations, temporary assignments, and promotions, and just-in-time training to upskill, reskill, or broaden capabilities of the existing workforce.

NASA's Office of Diversity and Equal Opportunity (ODEO) is actively involved in this strategic workforce planning effort, while also continuing to lead NASA diversity and civil rights policies, programs, and services.

2. Administrator Nelson, in its FY2022 budget request NASA proposed an additional $5 billion between FY22 and FY26 to support competitive lander missions to the Moon under the Lunar Exploration and Transportation Services (LETS) effort. Will you please share the purpose of the LETS contract and how you envision this funding being spent?

A: Future lunar exploration transportation services will be acquired through competitive selection, thus competition among bidders for the Lunar Exploration and Transportation Services (LETS) acquisition is key. Having multiple bidders helps to put downward pressure on prices and incentivizes innovation. Once selections have been made, the acquisition approach can also have a substantial impact on motivating contractors and controlling costs. NASA intends for LETS to make use of fixed-price contracts, milestone-based performance incentives (payment is withheld unless milestones are met), and price caps. The additional funding requested displayed in the FY 2022 Budget for FY 2023 and beyond is intended to provide NASA with the funding resources necessary to support competition for these services.

3. Administrator Nelson, I was pleased to see the agency's FY 2022 budget request outlined critical investments in Space Technology to further key research and develop partnerships and collaborations with industry, academia, and other government agencies. Could you discuss NASA's work with its partners to develop and demonstrate affordable, autonomous manufacturing construction technologies? Could you also describe what role will these technologies play in both lunar and Mars missions to establish permanent presences in those environments?

A: To explore worlds beyond our home planet, cargo space and weight aboard our vehicles is limited, and often consumed by the many resources we will need for survival. To overcome this challenge, NASA is developing technologies to reuse the materials we will already be carrying and combine them with indigenous materials. The Agency is investing in advanced and autonomous manufacturing technologies, as well as technologies that could find and use available resources on the Moon and Mars to build out future infrastructure.

The Space Technology Mission Directorate (STMD) is currently partnering with industry and academia on investments that focus on the utilization of *in situ* materials for the construction of large-scale infrastructure elements like habitats, berms, landing pads, blast shields, walkways, floors, storage facilities, and roads. These structures will provide protection to astronauts, hardware, and electronics while on the surface of an extraterrestrial body to enable on-location surface exploration.

One example is NASA's Moon to Mars Planetary Autonomous Construction Technologies (MMPACT) project. STMD is partnering with ICON, Space Exploration Architecture (SEArch+), the Bjarke Ingels Group (BIG), the Defense Innovation Unit (DIU), the Texas Air National Guard (TANG), the United States Air Force, RWBruce Associates LLC, Radiance Technologies, Blue Origin, and many other companies and universities on the utilization of lunar *in situ* materials for the on-demand construction of large-scale infrastructure elements that will provide protection of crewmembers, hardware, and electronics while on the surface of an extraterrestrial body to enable on-location surface exploration. In addition, STMD is partnered with MAXAR and Redwire to develop on-orbit servicing, assembly, and manufacturing technologies which, once demonstrated could have far-reaching applications for in-space and planetary usage.

Submitted by Mr. Sherman

1. **To explore with humans in deep space you need a heavy lift capability, we now have that national capability with the SLS. Now that it is developed, we need to ensure it remains robust and affordable. One of the best ways to do that is to have a regular cadence of use. SLS costs would drop significantly if it had more missions. You have noted that SLS could be used for multiple types of missions besides sending humans to deep space.**

   Can you provide more detail on NASA's plan for keep a regular cadence of SLS mission, and have you spoke to your colleagues in the national security space about using SLS since the Delta IV Heavy is being retired?

A: NASA's crewed deep space missions are the only near-term user of the SLS, and SLS is a cornerstone of our deep space activities. SLS, Orion and the Exploration Ground Systems (EGS) are being designed to be capable of supporting a long-term flight rate of one per year, with plans to implement affordability initiatives to ensure that this cadence can be achieved at affordable expenditure levels. The actual cadence of missions will be based on mission needs, available resources, and operational costs.

NASA will also continue to evaluate opportunities to use these assets, on cost reimbursable basis, as a service to other Government and non-Government entities where use of this asset is consistent with national policy and needs.

2. **The SLS is currently being assembled, NASA is ready for launching hopefully by the end of the year, and second SLS and Orion are well on their way to being completed. The backbone of the architecture to finally return humans to deep space is ready.**

   Can you elaborate on how NASA plans to keep and possibly accelerate that momentum so we can ensure that we are not over-taken by the Chinese?

A: The foundation for our return to the Moon is NASA's deep space transportation system and the SLS, EGS, and Orion are critical elements in achieving the goal of returning astronauts to the Moon. Artemis I will initiate the use of the SLS capabilities with the first uncrewed test flight in 2021 or 2022. The Artemis I mission will demonstrate the envelope of system capabilities and safe and successful deep space operations for a mission lasting about month. Artemis II will be a crewed test flight of a mission to lunar orbit and back in late 2023. Artemis III will return humans to the lunar surface with SLS / Orion providing safe transport to and from lunar orbit. Artemis IV will transition the SLS from Block 1 to Block 1B, enabling advanced lifting capabilities with the introduction of the Exploration Upper Stage (EUS). Future Artemis missions of the SLS will deliver crew onboard Orion along with co-manifested payloads to build up the Gateway on which the astronauts will be able to conduct research and take extended trips down to the lunar surface. Following Artemis IV, NASA will maintain the momentum with a yearly flight cadence of the SLS transport of crew to deep space and back as the Agency builds up its sustainable lunar capabilities.

The incremental build-up of capabilities on and around the Moon is supported by the SLS rocket, which is a key element in NASA's plans to keep the U.S. in the forefront of space exploration. NASA plans to continue this buildup as quickly and affordably as possible.

3. **Recently, China and Russia publicly discussed their plans to work together to send humans to the Moon. You have discussed the threat of China's growing capability and aggressive plans. Combining Russia's expertise and China's financial resources could help China accelerate their**

plans to be leaders in deep space. NASA's current approach to human deep space exploration, specifically HLS, puts the U.S. government in the back seat and puts a single private company in the driver seat with an incredibly complicated unproven approach.

How do you ensure that U.S. maintains leadership in human space exploration and support a robust and diverse U.S. supply chain?

A: The follow-on activity to the initial Human Landing System (HLS) landing, the Lunar Exploration Transportation Services (LETS) contract, will continue to push the United States toward a consistent, sustained presence on the lunar surface. This competitive contract will be open to private industry, which NASA is keeping engaged through the Next Space Technologies for Exploration Partnerships (NextSTEP) Appendix N contract: Sustainable Human Landing System Studies and Risk Reduction, awarded to five companies in late FY 2021. Diverting from the current acquisition strategy will delay NASA's plan of returning its astronauts to the Moon and developing a sustainable human presence.

Do you see a risk of the U.S. falling behind China in space exploration, if that company is not successful?

A: No. Russia and China are aiming to land astronauts on the Moon by 2035, around a decade after the United States plans to return. NASA and the Appendix A awardee will be working together to ensure the success of the crewed demonstration mission, and NASA will be working with one or more LETS awardees to ensure the success of future missions to the lunar surface. NASA is extremely confident in the ability of the joint government-industry team to safely achieve the goal of re-establishing a presence on the lunar surface.

Submitted by Ms. Lofgren

1. **My understanding is that it is customary for NASA to use the senior review to evaluate a program's merit and to determine the future of such programs at the agency. The Stratospheric Observatory for Infrared Astronomy (SOFIA) is scheduled for its senior review in Fiscal Year 2022 (FY22). However, as with the FY21 budget request, NASA is again proposing to cancel SOFIA in FY22.**

    - **Why is NASA proposing the discontinuation of a program before a proper senior review can be completed? Does this indicate a shift in operating posture or loss of confidence in the senior review process?**

A: NASA has not lost confidence in the Senior Review process. The Senior Review process is used, per the NASA Authorization Act of 2005, when expert external assessment is required to determine whether the cost of extending a mission is justified based on the science and other benefits expected. The Stratospheric Observatory For Infrared Astronomy (SOFIA) completed its prime mission in 2019. It was NASA's plan to place SOFIA into the Senior Review in 2019, but Congress prohibited NASA from including SOFIA in the 2019 Senior Review. Since 2019, SOFIA has experienced ongoing operational and technical challenges. Because SOFIA has not met operational or science output expectations, the FY 2022 President's Budget Request proposes terminating SOFIA in order to focus resources on missions with higher scientific return.

2. **As Congress works on various infrastructure proposals, my colleagues and I on the Committee have been advocating for the inclusion of our nation's science infrastructure. Much of our science infrastructure is severely outdated, which severely limits our ability to remain competitive.**

    - **Given the number of infrastructure projects on NASA's list, how will the agency prioritize selection should the full funding request not be made available immediately?**

A: NASA utilizes funding provided in the Safety, Security, and Mission Services (SSMS) and Construction and Environmental Compliance and Restoration (CECR) accounts to support the sustainment of its vast portfolio of unique and aging critical infrastructure. NASA must balance spending on the maintenance of assets and infrastructure, repairs and renewal of failing assets, and the demolition and replacement of unneeded assets. Maintenance activities drive SSMS funding decisions, while repairs, renewals (including new construction) and associated demolition drive CECR spending decisions.

NASA facilities projects are funded through Construction of Facilities (CoF), within the CECR account, and are prioritized based upon mission requirements and long-term sustainability. These long-established priorities for ensuring the health and viability of mission-critical infrastructure are as follows:

- Construct new facilities and replace or upgrade existing infrastructure to support NASA mission requirements and timeline;
- Design facilities and infrastructure solutions to support construction and repairs while optimizing sustainability, increasing efficiency, and reducing NASA's footprint;
- Demolish unneeded and degraded facilities to avoid costs and improve sustainability;
- Invest in energy and water savings opportunities to improve NASA's environmental stewardship; and
- Comply with mandates, regulations, and general best practices to protect the health and wellness of the environment, NASA's workforce, and the general public.

NASA will continue to keep these priorities in focus as it addresses infrastructure challenges in FY 2022 and beyond. The Office of Strategic Infrastructure employs a selection of established tools and indexes to ensure careful analysis of infrastructure assets. These enable assessments of the age and condition of individual facilities, and their potential for associated risks to missions, safety, and the environment, as well as the appropriateness of a given facility to the requirements of its current use, which also affects risk outlooks. Further, NASA's Master Planning process provides an infrastructure planning framework that looks ahead to articulate a vision, Center by Center, for successful alignment of physical infrastructure and real property assets to evolving and future mission requirements. The facilities master planning process provides guidelines that further support prioritizing projects within funding allocations.

Despite these efforts however, a history of reductions to NASA infrastructure resources inevitably results in increased risk to missions and operations, and constrains the Agency's ability to address these challenges. Over 80 percent of NASA facilities are beyond their constructed design life and over 60 percent of NASA's workforce resides in facilities noted as being in "fair" or below condition. NASA mission activities increasingly depend on Apollo-era infrastructure that is degrading. NASA's backlog of delayed maintenance and deferred projects continues to increase, the effect of which is a further compounding of risk caused by unplanned repairs and maintenance costs and delays. Support for NASA's FY 2022 full budget request for SSMS and CECR is critical to NASA's continued mission success in the future.

Appendix II

Additional Material for the Record

QUESTION SUBMITTED BY REPRESENTATIVE BRIAN BABIN

Rep. Babin Material for the Record Request

Question: Has NASA specifically identified other customers for our human landers or spacesuits that would make these commercial ventures viable without NASA funding?

Response: NASA is utilizing a development and acquisition model for human landers and space suits where the landers and suits are not owned by NASA but by commercial ventures in which NASA is but one of the paying customers, and has received input from industry that this approach is both cost efficient for NASA and advantageous to industry. The services based approach for human lander and spacesuits and the Commercial low-Earth orbit (Commercial LEO) effort are supporting private industry and private citizen interest in space exploration and extra vehicular activity. NASA has received requests to use its suits and allow for extravehicular activity (EVA) from the International Space Station on private astronaut missions. In addition, U.S. industry has made public statements about privately sending people to the moon for Lunar surface exploration and initiating commercial space stations which would require EVA capability. NASA's approach to being the first paying customer on services contracts for space exploration is seeing success in areas such as commercial crew with Inspiration4, a private astronaut orbital mission utilizing the SpaceX Dragon.

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